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(54) **STABLE SILK PROTEIN FRAGMENT COMPOSITIONS**

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A61K 8/49 (2006.01)

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(52) **U.S. Cl.**
CPC *A61K 8/64* (2013.01); *A45D 33/00* (2013.01); *A61K 8/02* (2013.01); *A61K 8/0216* (2013.01); *A61K 8/042* (2013.01); *A61K 8/19* (2013.01); *A61K 8/27* (2013.01); *A61K 8/29* (2013.01); *A61K 8/365* (2013.01); *A61K 8/4953* (2013.01); *A61K 8/676* (2013.01); *A61K 8/735* (2013.01); *A61K 8/922* (2013.01); *A61K 8/97* (2013.01); *A61K 8/987* (2013.01); *A61K 9/08* (2013.01); *A61K 38/00* (2013.01); *A61K 38/012* (2013.01); *A61Q 17/04* (2013.01); *A61Q 19/00* (2013.01); *A61Q 19/007* (2013.01); *A61Q 19/02* (2013.01); *A61Q 19/08* (2013.01); *C07K 1/12* (2013.01); *C07K 14/43586* (2013.01); *A61K 2800/591* (2013.01); *A61K 2800/72* (2013.01); *A61K 2800/74* (2013.01); *A61K 2800/75* (2013.01)

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This patent is subject to a terminal disclaimer.

(58) **Field of Classification Search**
None
See application file for complete search history.

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(56) **References Cited**

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U.S. PATENT DOCUMENTS

26,501 A 12/1859 Kendrick et al.
64,499 A 5/1867 Daubert
445,875 A 2/1891 Brickell
687,221 A 11/1901 Gaff et al.
5,902,932 A 5/1999 Bills et al.
6,432,910 B2 * 8/2002 Nakagawa A61L 15/50 428/96
7,632,873 B2 12/2009 Mouglin
(Continued)

Related U.S. Application Data

(63) Continuation of application No. 14/503,021, filed on Sep. 30, 2014, now Pat. No. 9,187,538.

FOREIGN PATENT DOCUMENTS

(60) Provisional application No. 61/884,820, filed on Sep. 30, 2013, provisional application No. 62/000,928, filed on May 20, 2014, provisional application No. 62/036,450, filed on Aug. 12, 2014.

WO 2012/145739 10/2012
WO 2014/011644 1/2014
WO 2014/145002 9/2014

OTHER PUBLICATIONS

(51) **Int. Cl.**
A61K 9/08 (2006.01)
A61K 8/02 (2006.01)
A61K 38/01 (2006.01)
A61K 8/64 (2006.01)
C07K 1/12 (2006.01)
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A61K 8/98 (2006.01)
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A61K 8/29 (2006.01)
A61K 8/67 (2006.01)
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A61K 8/92 (2006.01)
A61K 8/04 (2006.01)
A61K 8/19 (2006.01)

Wang, Q., et al. Biomacromolecules (2012), 14; pp. 285-289.*
(Continued)

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(57) **ABSTRACT**

A composition is disclosed that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogeneous, wherein the composition between 0 ppm to about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm to about 500 ppm of organic residuals.

15 Claims, 105 Drawing Sheets

(56)

References Cited

U.S. PATENT DOCUMENTS

7,635,755 B2 12/2009 Kaplan et al.
 7,674,882 B2 3/2010 Kaplan et al.
 7,727,542 B2 6/2010 DiBenedetto et al.
 8,071,722 B2 12/2011 Kaplan et al.
 8,187,616 B2 5/2012 Wang et al.
 8,288,347 B2 10/2012 Collette et al.
 8,420,077 B2 4/2013 Altman et al.
 8,501,172 B2 8/2013 Kaplan et al.
 8,551,538 B2 10/2013 Qian
 8,614,293 B2 12/2013 Kaplan et al.
 8,623,398 B2 1/2014 Altman et al.
 8,628,791 B2 1/2014 Altman et al.
 8,633,027 B2 1/2014 Altman et al.
 8,685,426 B2 4/2014 Altman et al.
 8,715,740 B2 5/2014 Wang et al.
 8,741,281 B2 6/2014 Van Epps et al.
 8,894,992 B2 11/2014 Van Epps et al.
 8,900,571 B2 12/2014 Van Epps et al.
 8,926,963 B2 1/2015 Van Epps et al.
 2001/0051815 A1 12/2001 Esplin
 2002/0077629 A1 6/2002 Hoffman et al.
 2002/0082220 A1 6/2002 Hoemann et al.
 2002/0111591 A1 8/2002 Mckinnon et al.
 2003/0099630 A1* 5/2003 DiBenedetto A61L 24/0084
 424/94.64
 2003/0139752 A1 7/2003 Pasricha et al.
 2003/0206897 A1 11/2003 O'Prey et al.
 2003/0208209 A1 11/2003 Gambale et al.
 2003/0220646 A1 11/2003 Thelen et al.
 2003/0229361 A1 12/2003 Jackson
 2003/0236555 A1 12/2003 Thornes
 2004/0073176 A1 4/2004 Utterberg
 2004/0127907 A1 7/2004 Dakin et al.
 2004/0191199 A1 9/2004 Mouglin
 2004/0219630 A1 11/2004 Tsubouchi
 2004/0224406 A1* 11/2004 Altman A61F 2/08
 435/395
 2004/0265260 A1 12/2004 Tsubouchi et al.
 2004/0267317 A1 12/2004 Higgins et al.
 2005/0004670 A1 1/2005 Gebhardt et al.
 2005/0021148 A1 1/2005 Gibbs
 2005/0049598 A1 3/2005 West, Jr. et al.
 2005/0090827 A1 4/2005 Gedebou
 2005/0107882 A1 5/2005 Stone et al.
 2005/0130301 A1 6/2005 Mckay et al.
 2005/0149118 A1 7/2005 Koyfman et al.
 2005/0171604 A1 8/2005 Michalow
 2005/0177237 A1 8/2005 Shappley et al.
 2005/0192632 A1 9/2005 Geissler et al.
 2005/0251153 A1 11/2005 Sakamoto et al.
 2005/0251209 A1 11/2005 Saadat et al.
 2005/0261642 A1 11/2005 Weston
 2006/0004364 A1 1/2006 Green et al.
 2006/0178743 A1 8/2006 Carter
 2006/0195106 A1 8/2006 Jones et al.
 2006/0229623 A1 10/2006 Bonutti et al.
 2006/0229676 A1 10/2006 Doll et al.
 2006/0241776 A1 10/2006 Brown et al.
 2006/0241781 A1 10/2006 Brown et al.
 2009/0234026 A1 9/2009 Kaplan et al.
 2011/0076384 A1 3/2011 Cannizzaro et al.
 2011/0105402 A1 5/2011 Kim et al.
 2011/0223153 A1 9/2011 Lu et al.
 2012/0070427 A1 3/2012 Kaplan et al.
 2012/0076771 A1 3/2012 Vepari et al.
 2012/0123519 A1 5/2012 Lovett et al.
 2012/0187591 A1* 7/2012 Wang A61K 9/5169
 264/9
 2012/0244143 A1 9/2012 Lo et al.
 2013/0045278 A1 2/2013 Qian

2013/0165004 A1 6/2013 Kaplan et al.
 2013/0240251 A1 9/2013 Kaplan et al.
 2013/0287742 A1 10/2013 Kaplan et al.
 2014/0134240 A1 5/2014 Kaplan et al.
 2015/0038043 A1 2/2015 Kaplan et al.
 2015/0056293 A1 2/2015 Wang et al.

OTHER PUBLICATIONS

Gilbert et al., "Dispersity in Polymer Science", Pure Appl. Chem., 2009, 81(2), pp. 351-353.
 Cetinkaya et al., "Silk Fiber Mechanics from Multiscale Force Distribution Analysis", Biophysical Journal, Mar. 2011, 100(5), pp. 1298-1305.
 Cho et al., "Molecular Weight Distribution and Solution Properties of Silk Fibroins with Different Dissolution Conditions", International Journal of Biological Macromolecules, Jun. 2012, 51, pp. 336-341.
 Fan et al., "Vitamin C-reinforcing Silk Fibroin Nanofibrous Matrices for Skin Care Application", RSC Advances, Mar. 2, 2012, pp. 4110-4119.
 Hardy et al., "Polymeric Materials Based on Silk Proteins", Polymer, Aug. 2008, 49(20), pp. 4309-4327.
 Hoffman et al., "Silk Fibroin as an Organic Polymer for Controlled Drug Delivery", Journal of Controlled Release, Mar. 2006, 111(1-2), pp. 219-227.
 Hyde et al., "Molecular Weight of Silk Fibroin", Journal of Polymer Science, Apr. 1962, 58(166), pp. 1083-1088.
 Motta et al., "Stabilization of Bombyx mori Silk Fibroin/Sericin Films by Crosslinking with PEG-DE 600 and Genipin", Journal of Bioactive and Compatible Polymers, Mar. 2011, 26(2), pp. 130-143.
 Pandit et al., "Studies on Silk Fibroin I. Molecular Weight, Sedimentation Coefficient, Viscosity and Optical Rotation of Bilk Fibroin from Carbonate-Extracted Silk Fiber", Archives of Biochemistry and Biophysics, 149, Dec. 1972, pp. 259-268.
 Paula's Choice, "Jar Packaging: A Waste of Good Antioxidants & Money", http://www.paulaschoice.com/expert-advice/skin-care-basics/_jar-packaging, Aug. 28, 2013, 3 pages.
 Preda et al., "Bioengineered Silk Proteins to Control Cell and Tissue Functions" Protein Nanotechnology: Protocols, Instrumentation, and Applications, Methods in Molecular Biology, 2013, 996, Chapter 2, pp. 19-41.
 Rockwood et al., "Materials Fabrication from Bombyx Mod Silk Fibroin", Nature Protocols, Sep. 2011, 6(10), pp. 1612-1631.
 Bah et al., "Regenerated Silk Fibroin from *B. mori* Silk Cocoon for Tissue Engineering Applications", International Journal of Environmental Science and Development, Dec. 2010, 1(5), pp. 404-408.
 Sielc, "Separation of Potassium", <http://www.sielc.com/compound-potassium.html>, Aug. 27, 2013, 5 pages.
 Nang et al., "Design and Engineering of Silk Fibroin Scaffolds with Biomimetic Hierarchal Structures", Chemical communications, 2013, 49, pp. 1431-1433.
 Nang et al., "Effect of Various Dissolution Systems on the Molecular Weight of Regenerated Silk Fibroin", BioMacromolecules, Dec. 2012, 14(1), pp. 285-289.
 Wang et al., "Stabilization of Vaccines and Antibiotics in Silk and Eliminating the Cold Chain", PNAS, Jul. 2012, 109 (30), pp. 11981-11986.
 Fournier, "Quantitative Data on the *Bombyx mori* L. Silkworm: A Reivew", Biochimie, Feb. 1979, 61(2), pp. 283-320.
 Wray et al., "Effect of Processing on Silk-Based Biomaterials: Reproducibility and Biocompatibility", Journal of Biomedical Materials Research Part: Applied Biomaterials, Oct. 2011, 99(1), pp. 89-101 (author manuscript).
 International Patent Application No. PCT/US14/58462, International Search Report, dated Mar. 2, 2015, 4 pages.

* cited by examiner

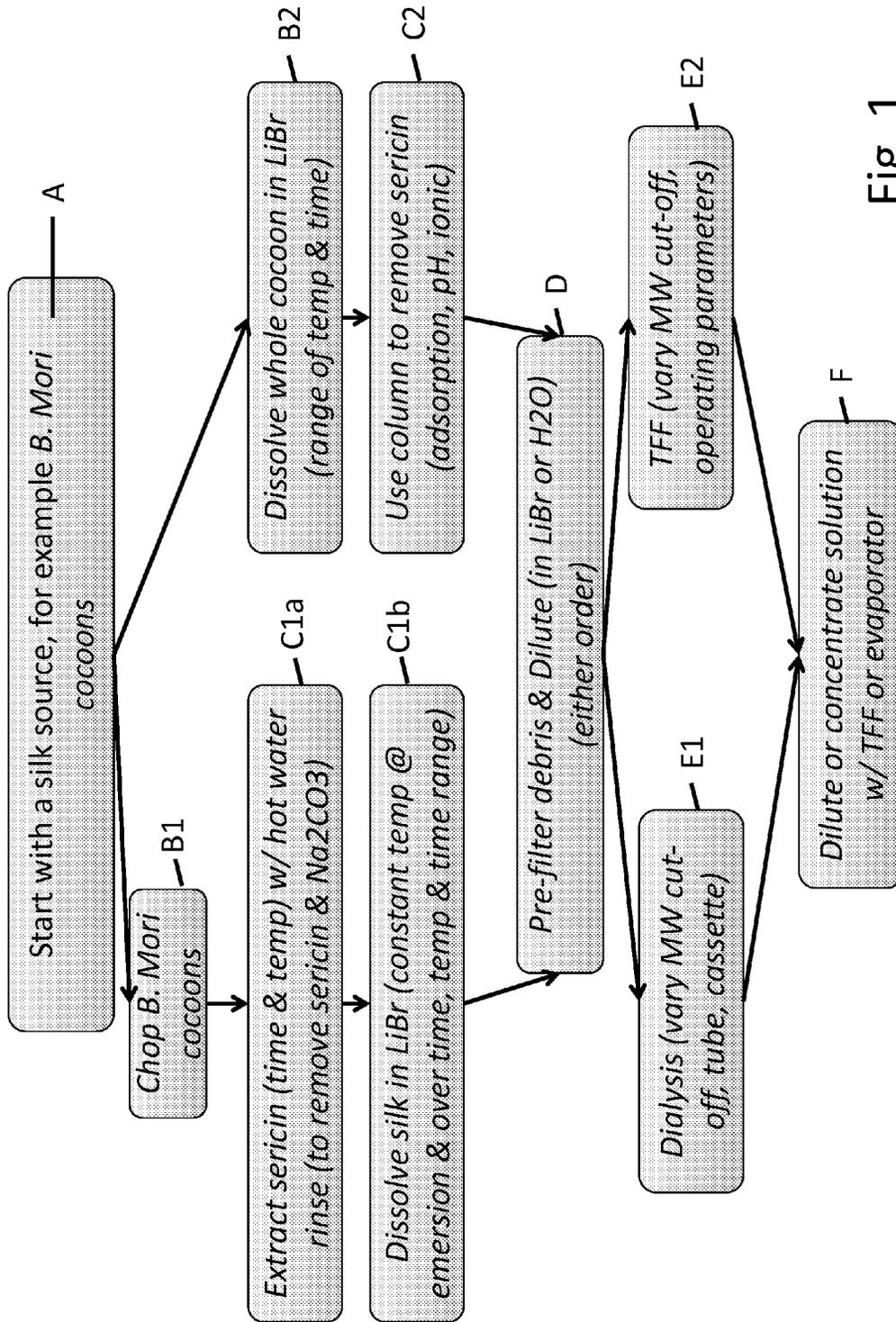


Fig. 1

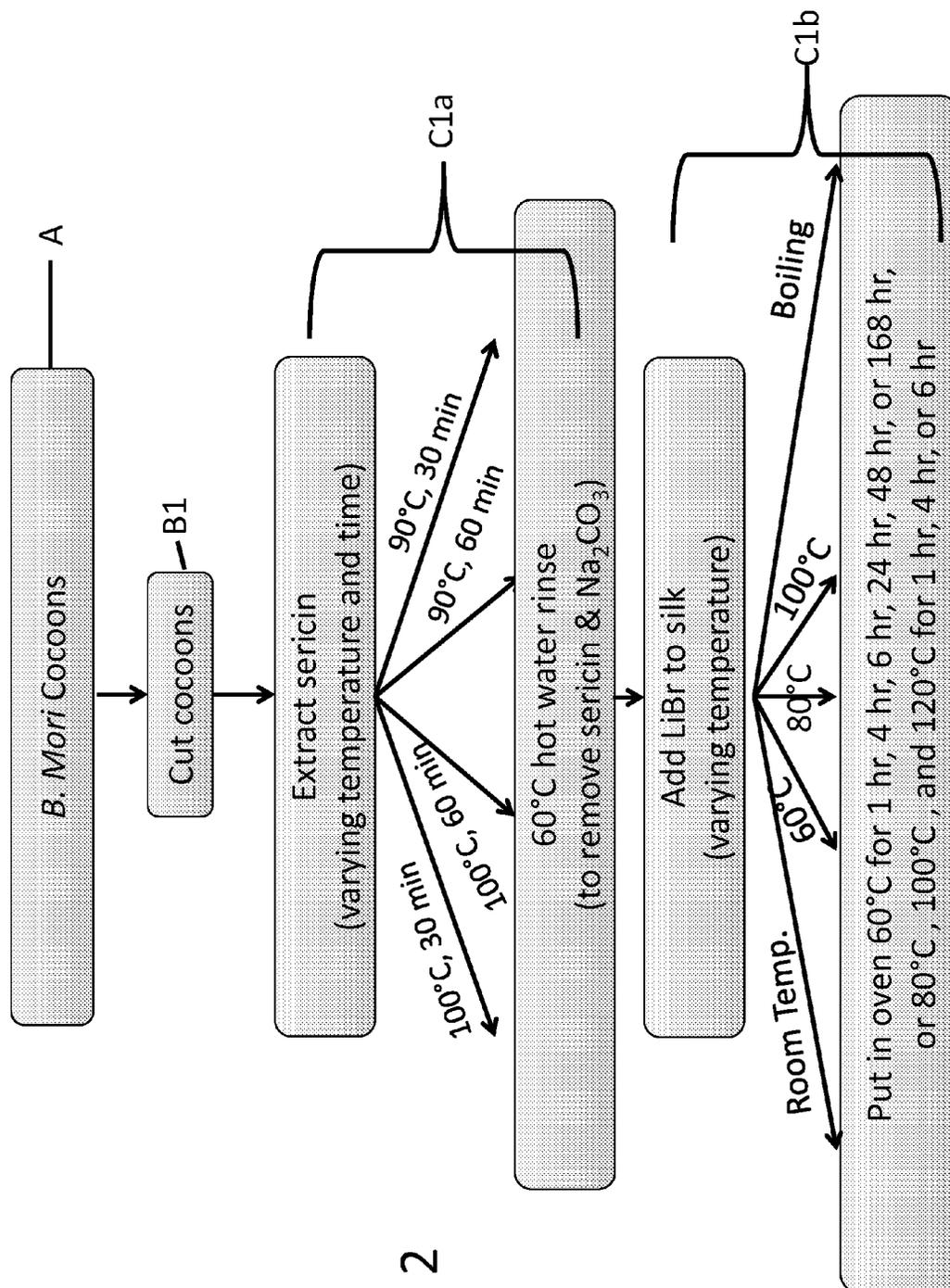


Fig. 2

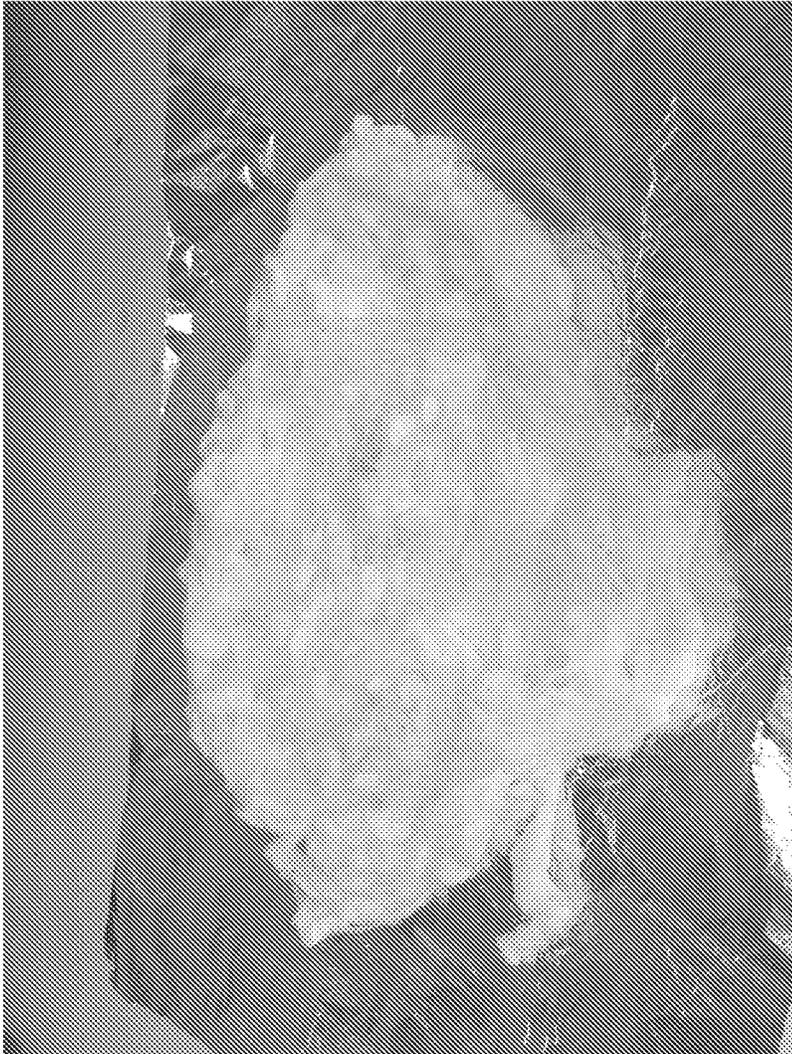


Fig. 3

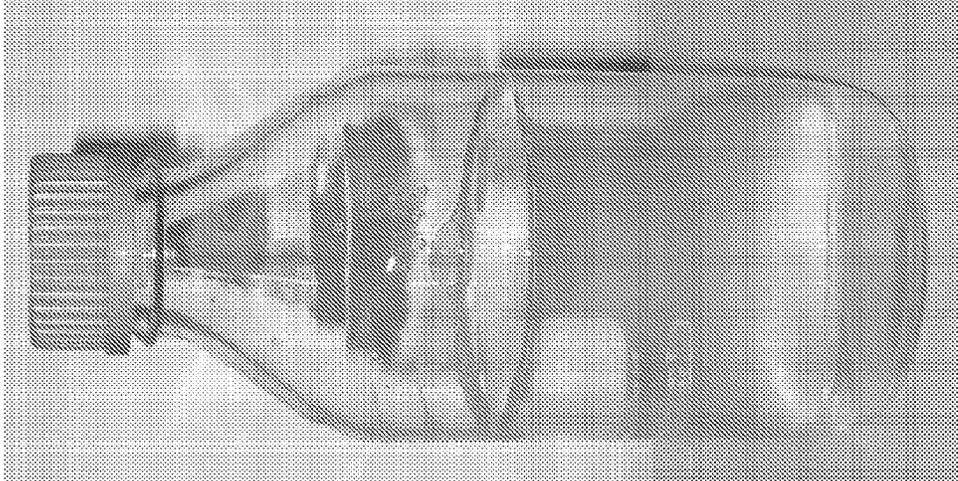


Fig. 4

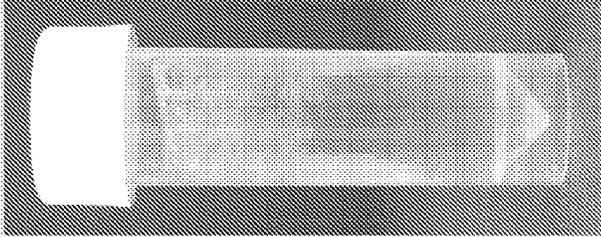
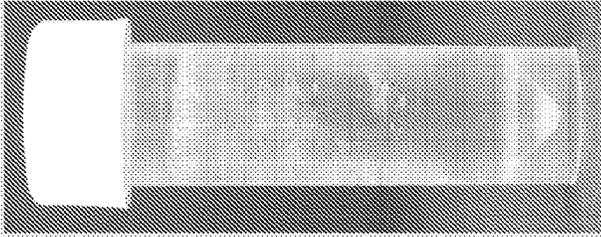
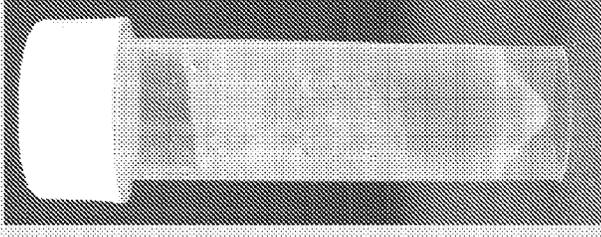
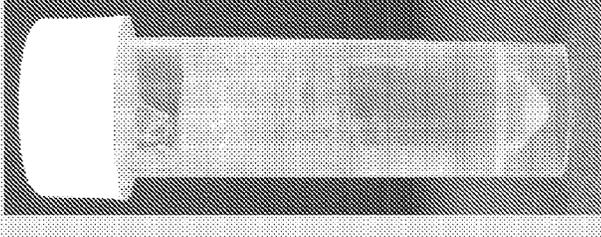
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	Some undissolved silk 	Some undissolved silk 	Significant amount of undissolved silk 	Significant amount of undissolved silk 

Fig. 5A

Fig. 5B

Fig. 5C

Fig. 5D

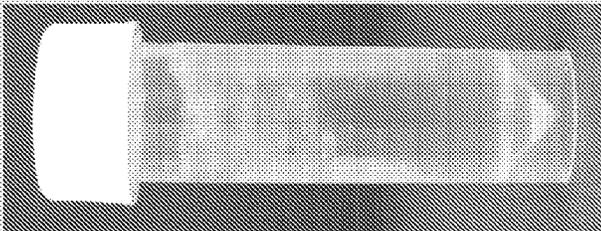
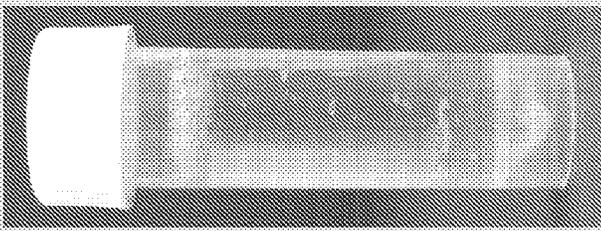
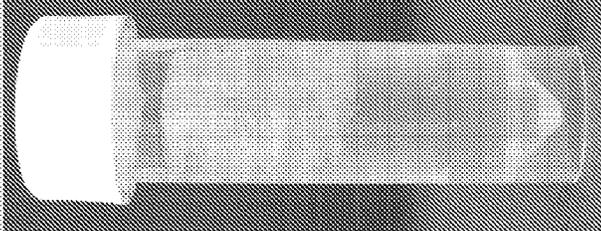
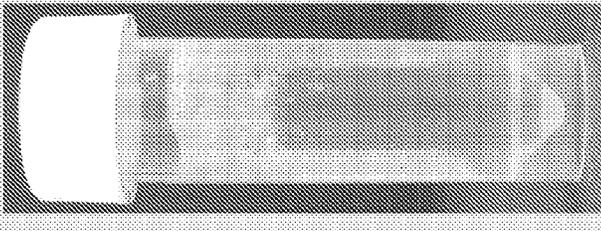
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
Some undissolved silk	Some undissolved silk	Small amount of undissolved silk	Significant amount of undissolved silk	Some undissolved silk
				
6 Hours				

Fig. 6A

Fig. 6B

Fig. 6C

Fig. 6D

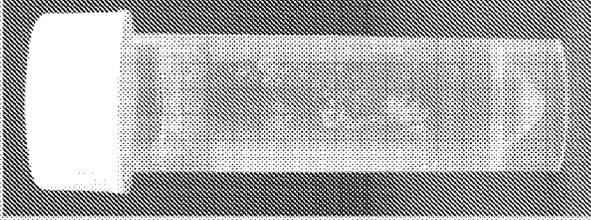
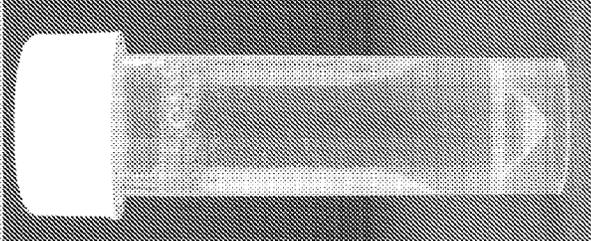
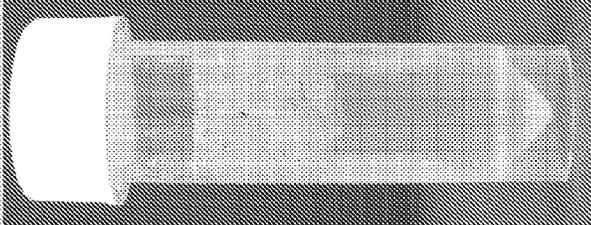
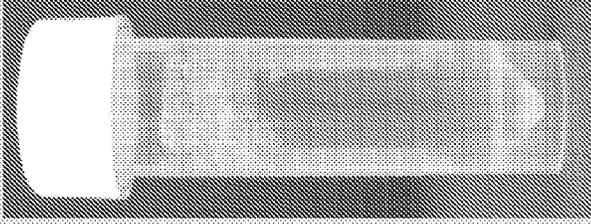
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
8 Hours	Small amount of undissolved silk 	Little to no undissolved silk 	Significant amount of undissolved silk 	Some undissolved silk 

Fig. 7A

Fig. 7B

Fig. 7C

Fig. 7D

Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
12 Hours	Small amount of undissolved silk	Little to no undissolved silk	Some undissolved silk	All but small amount of silk undissolved
				

Fig. 8A

Fig. 8B

Fig. 8C

Fig. 8D

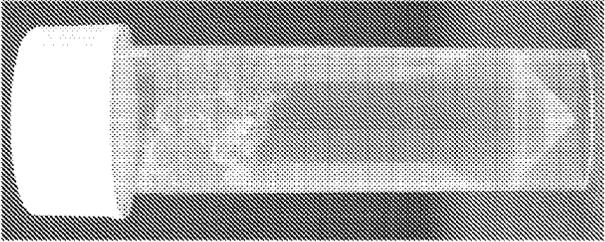
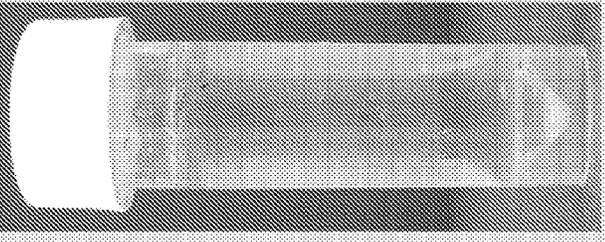
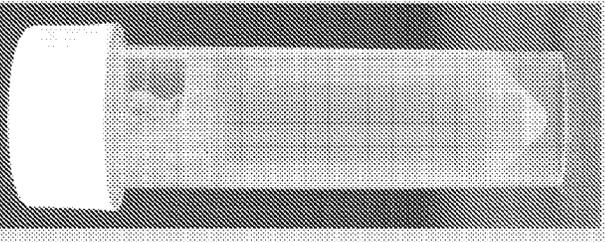
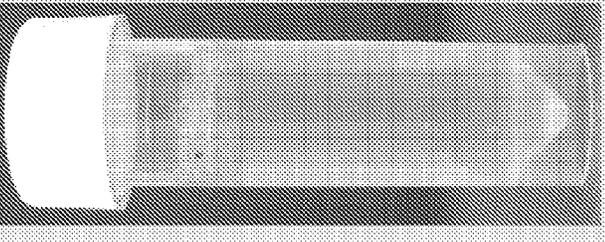
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
24 Hours	Small amount of undissolved silk 	Little to no undissolved silk 	Some undissolved silk 	All but small amount of silk undissolved 

Fig. 9A

Fig. 9B

Fig. 9C

Fig. 9D

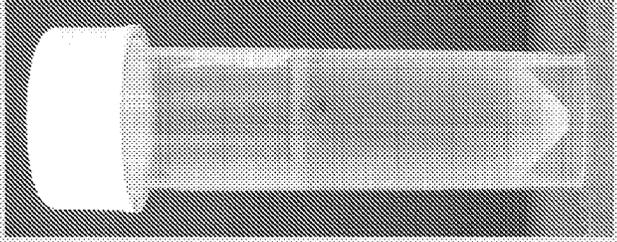
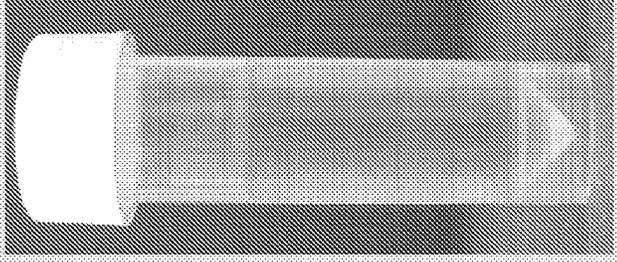
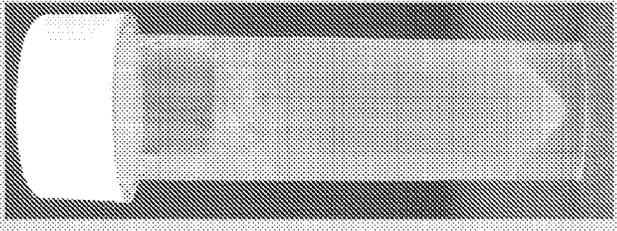
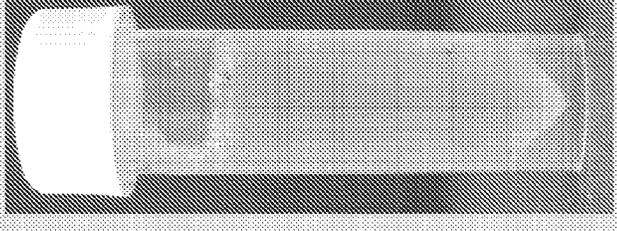
Time Point	1	2	3	4
	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
	No undissolved silk, only slightly cloudy	No undissolved silk, completely clear	Some undissolved silk	Slight amount of undissolved silk
				
168 Hours (1&2) 192 Hours (3&4)				

Fig. 10A

Fig. 10B

Fig. 10C

Fig. 10D

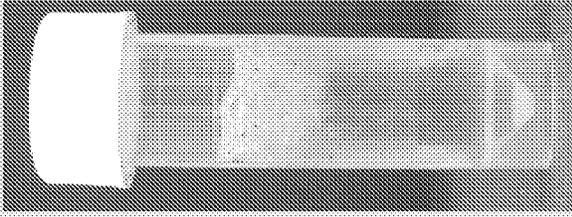
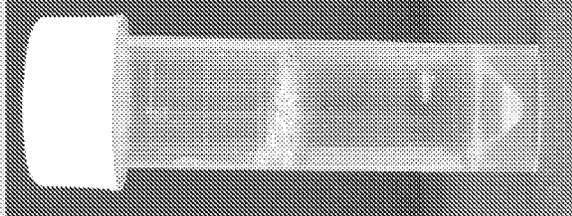
Sericin was extracted at 100° C, 60 min		
Hour 1	Hour 4	Hour 6
Large amount of undissolved silk	Small amounts of undissolved silk and debris	Small amount of floating debris
		

Fig. 11A

Fig. 11B

Fig. 11C

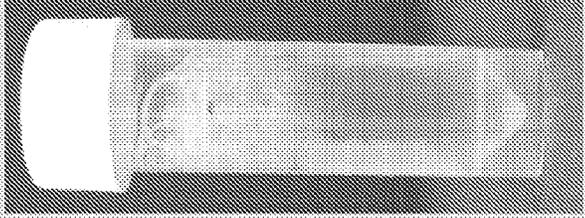
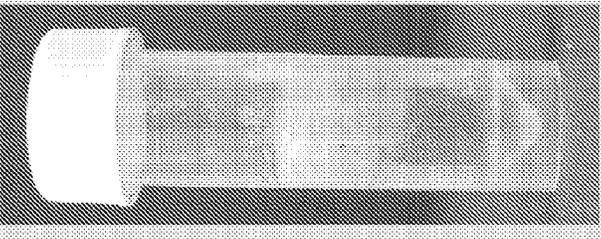
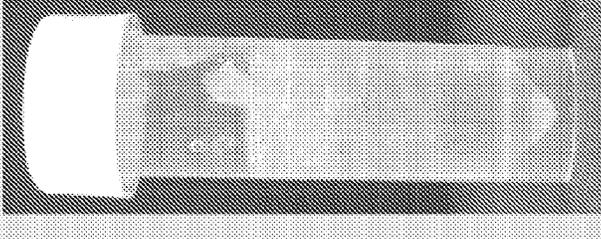
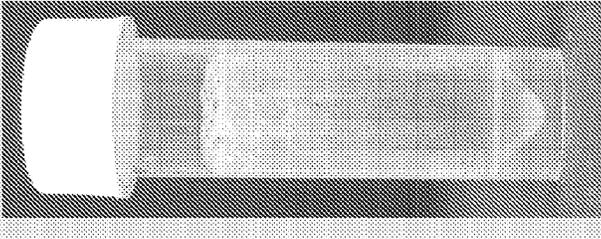
Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
1 Hour	Significant amount of undissolved silk 	Significant amount of undissolved silk and debris 	Significant amount of undissolved silk, highly viscous 	Significant amount of undissolved silk 

Fig. 12A

Fig. 12B

Fig. 12C

Fig. 12D

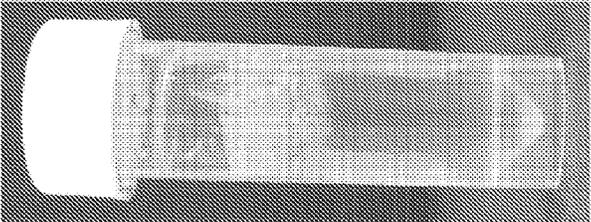
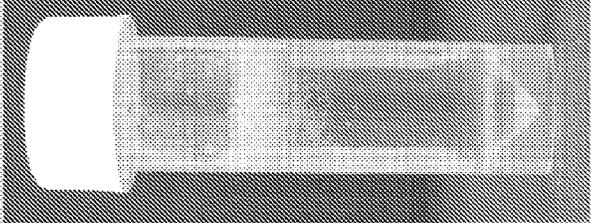
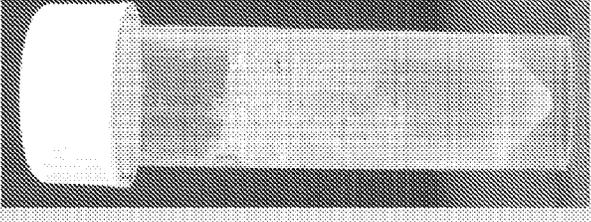
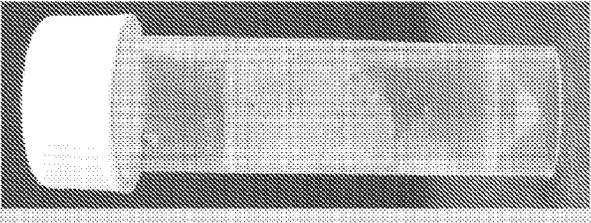
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	Some undissolved silk 	Some undissolved silk 	Significant amount of undissolved silk, highly viscous 	Some undissolved silk 

Fig. 13A

Fig. 13B

Fig. 13C

Fig. 13D

Figure 14

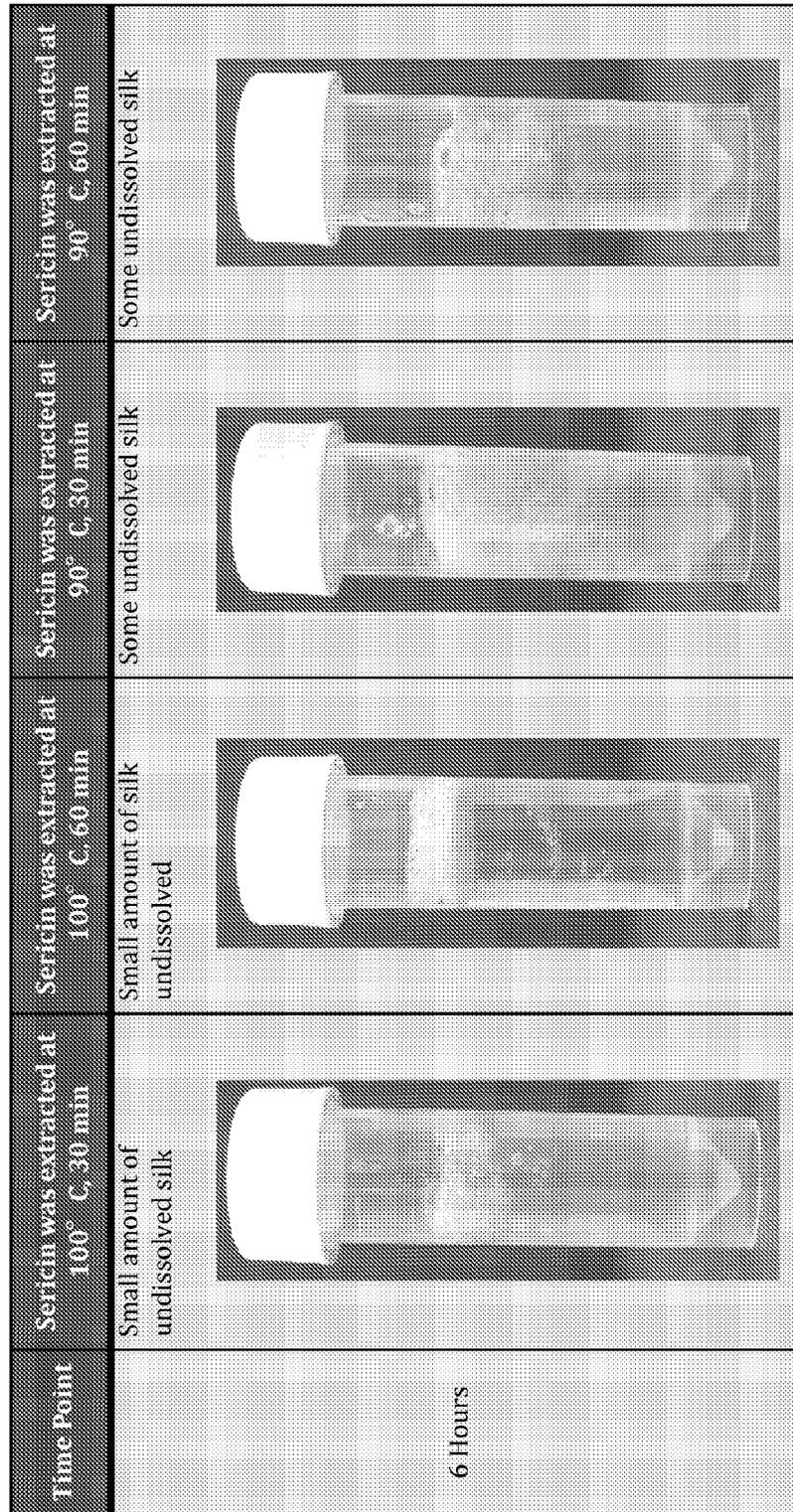


Fig. 14A

Fig. 14B

Fig. 14C

Fig. 14D

Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
1 Hour	Very small amount of undissolved silk, quite viscous; precipitate formed from bubbles	Less viscous than set 1, no undissolved silk	Highly viscous, some undissolved silk	Less viscous than set 3, some undissolved silk

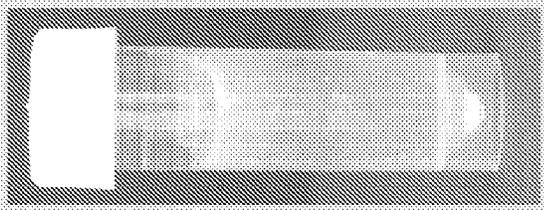
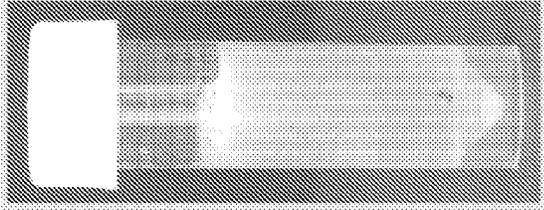
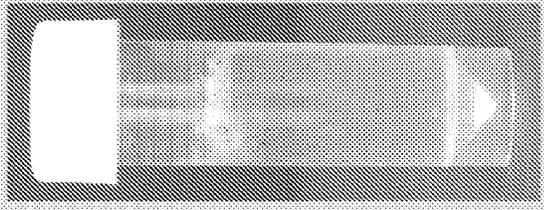
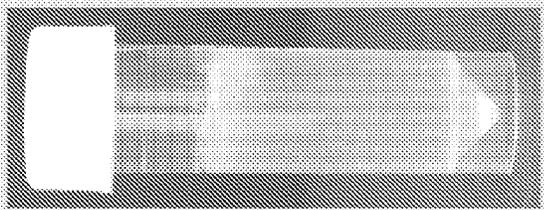


Fig. 15A

Fig. 15B

Fig. 15C

Fig. 15D

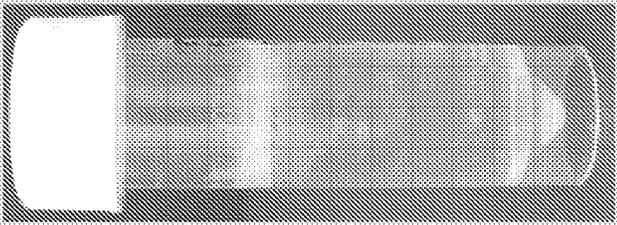
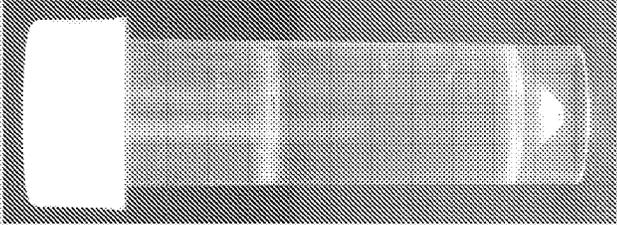
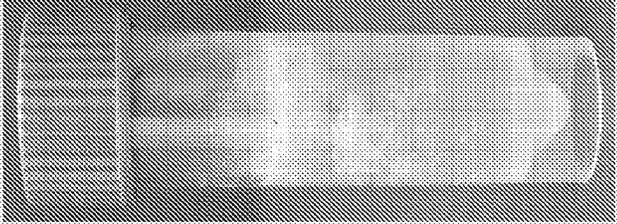
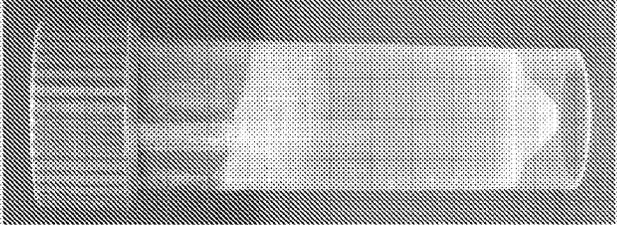
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	Extremely small amount of undissolved silk 	No undissolved silk 	Highly viscous, some undissolved silk 	Some undissolved silk 

Fig. 16A

Fig. 16B

Fig. 16C

Fig. 16D

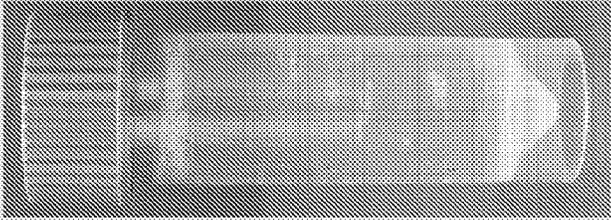
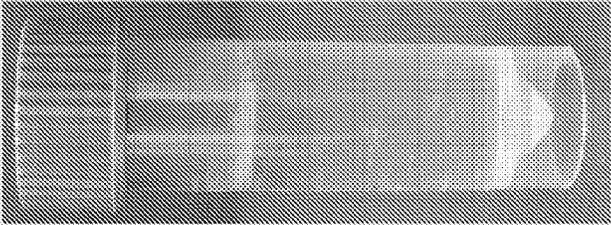
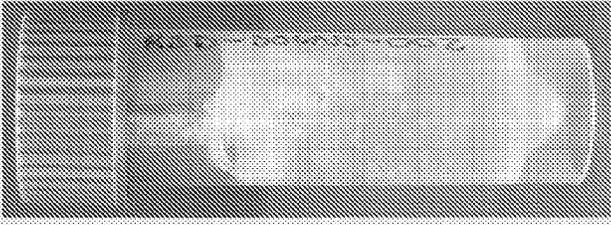
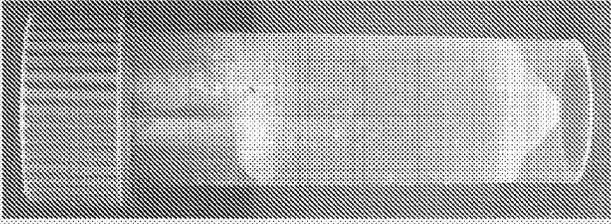
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
6 Hours	Extremely small amount of undissolved silk 	No undissolved silk 	Highly viscous, some undissolved silk 	Almost no undissolved silk 

Fig. 17A

Fig. 17B

Fig. 17C

Fig. 17D

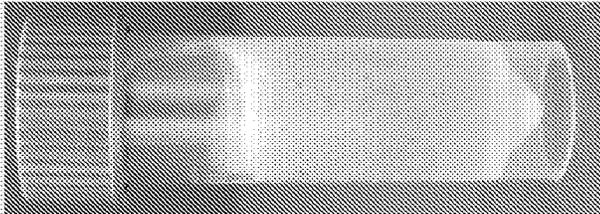
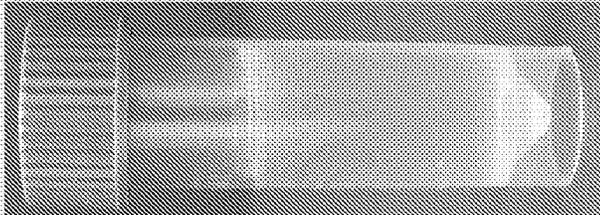
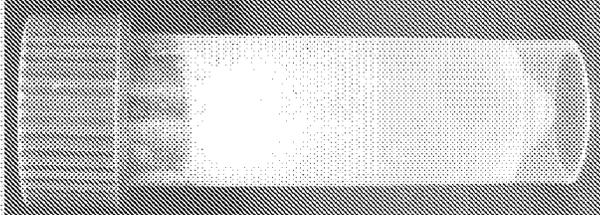
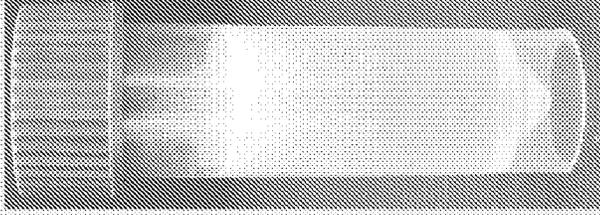
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
1 Hour	Small amount of undissolved silk, some precipitate from bubbles 	All silk dissolved, some precipitate from bubbles 	Some precipitate from bubbles and undissolved silk 	Some precipitate from bubbles and undissolved silk 

Fig. 18A

Fig. 18B

Fig. 18C

Fig. 18D

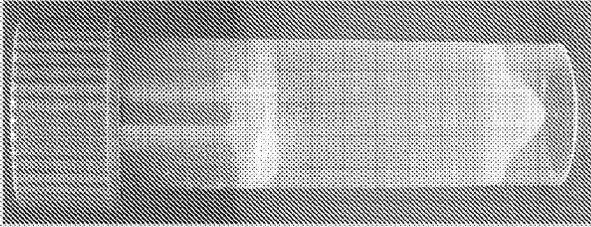
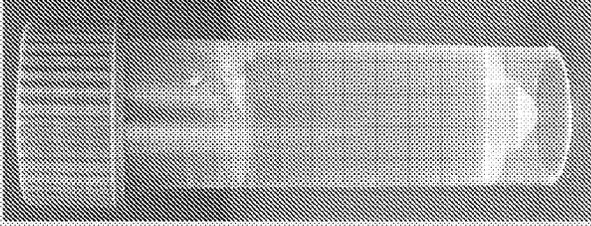
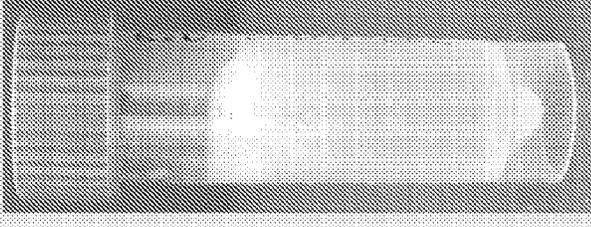
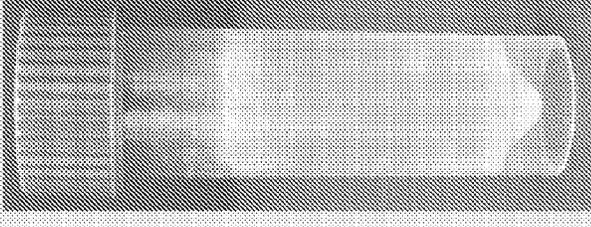
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	All silk dissolved, some precipitate from bubbles	Completely clear with no precipitate	Some undissolved silk	Some precipitate from bubbles, mostly clear solution
				

Fig. 19A

Fig. 19B

Fig. 19C

Fig. 19D

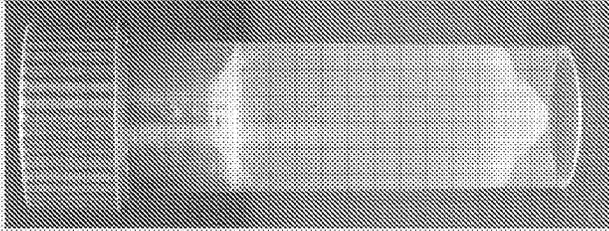
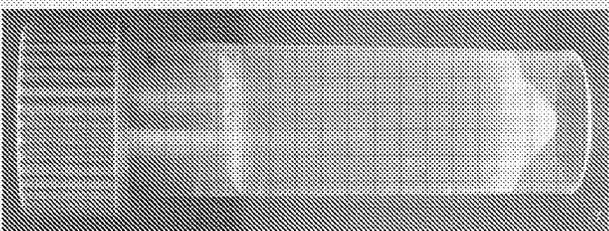
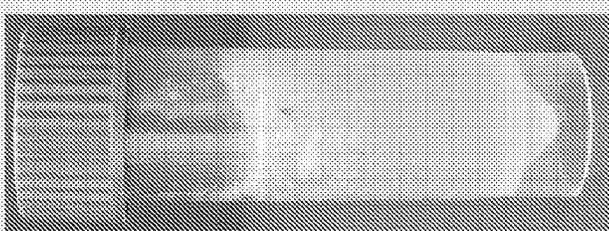
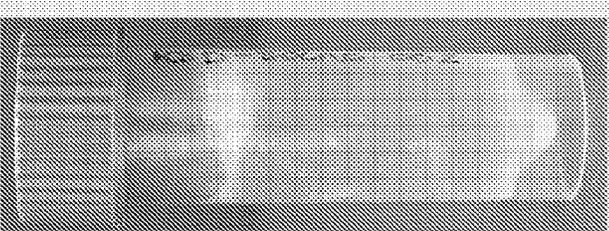
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
6 Hours	Some precipitate from bubbles, no undissolved silk 	Clear with no precipitate or silk 	Some undissolved silk 	Clear and no undissolved silk 

Fig. 20A

Fig. 20B

Fig. 20C

Fig. 20D

Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
1 Hour	Most silk dissolved, some precipitate from bubbles	Most silk dissolved, some slight precipitate from bubbles	Some precipitate from bubbles and significant amount of undissolved silk	Significant amount of undissolved silk

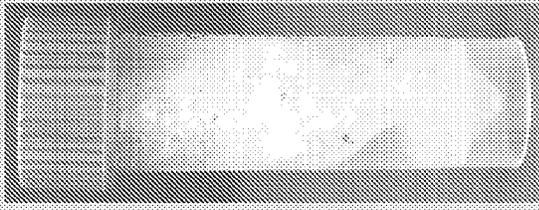
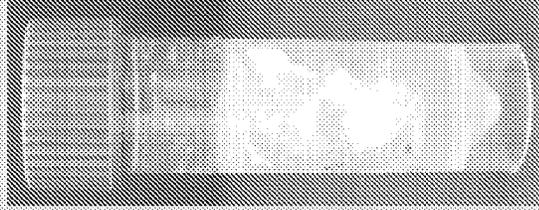
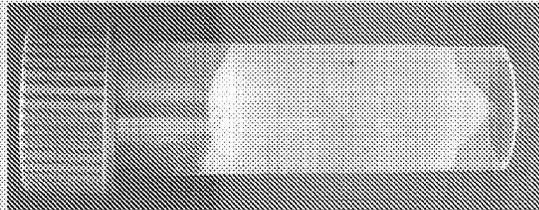
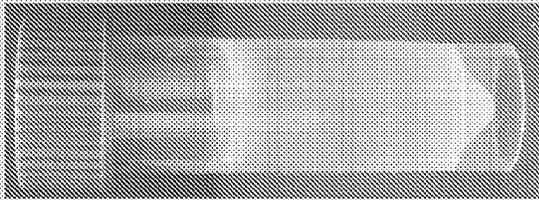


Fig. 21A

Fig. 21B

Fig. 21C

Fig. 21D

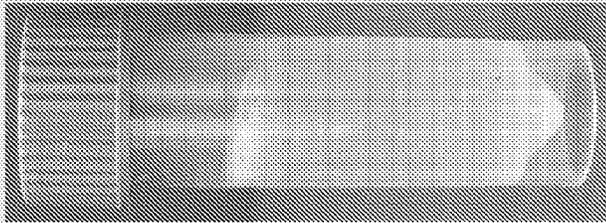
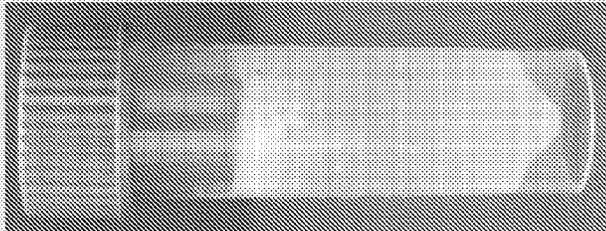
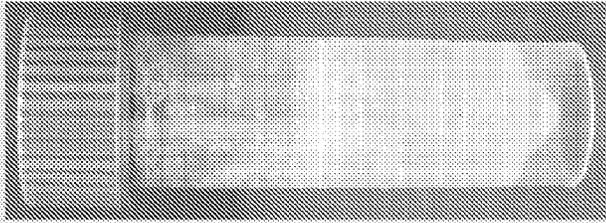
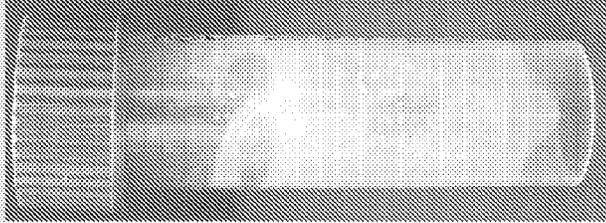
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	Completely clear, no silk or precipitate 	Some precipitate from bubbles 	Cloudy with some undissolved silk 	Very viscous with some undissolved silk 

Fig. 22A

Fig. 22B

Fig. 22C

Fig. 22D

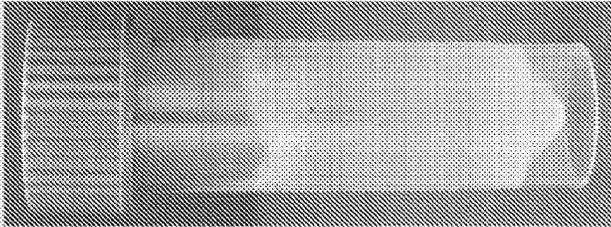
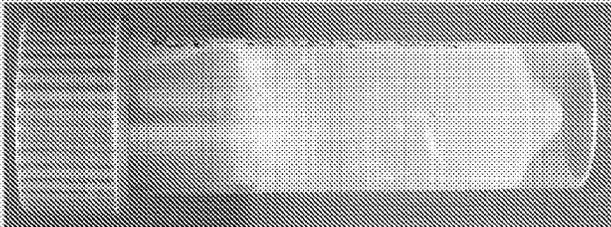
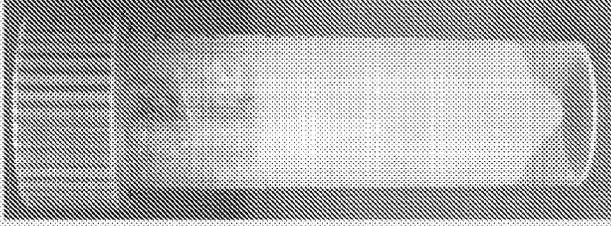
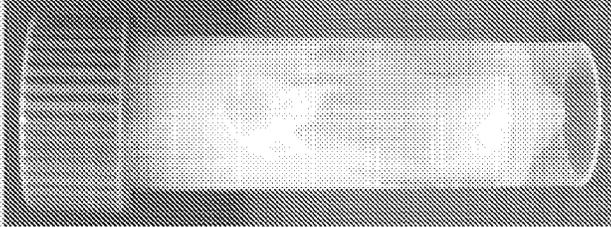
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
6 Hours	Slightly cloudy with silk particles on top 	Cloudy with precipitate from bubbles 	Highly viscous, cloudy, almost solid 	Highly viscous, cloudy, almost solid 

Fig. 23A

Fig. 23B

Fig. 23C

Fig. 23D

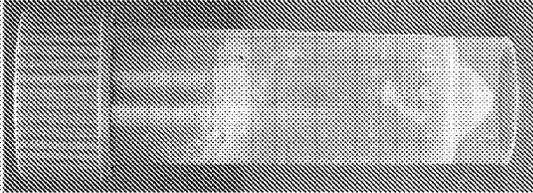
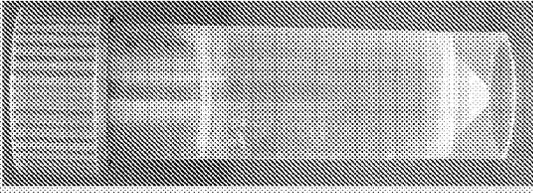
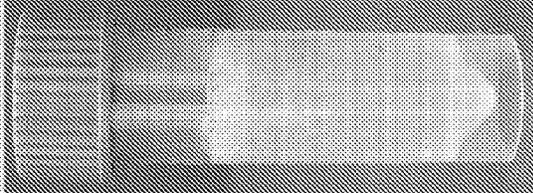
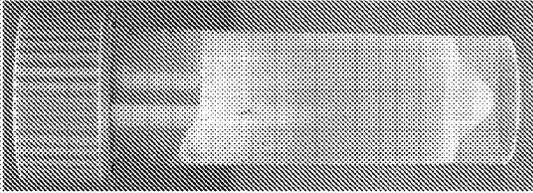
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
1 Hour	Some undissolved silk, viscosity slightly higher than set 2	Viscosity similar to water, nearly all silk completely dissolved and no precipitate, clear orange/yellow	Highly viscous, some undissolved silk and bubbles	Some undissolved silk but not too viscous
				

Fig. 24A

Fig. 24B

Fig. 24C

Fig. 24D

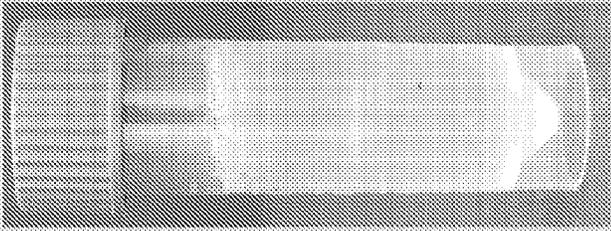
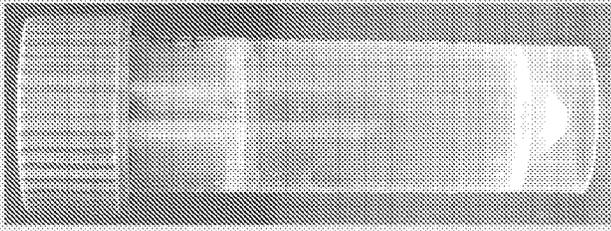
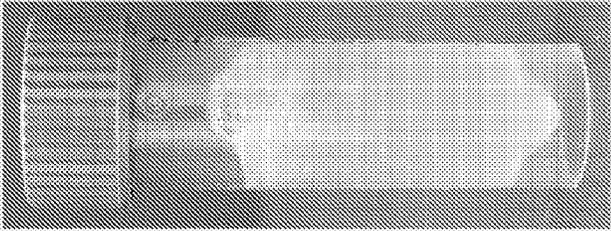
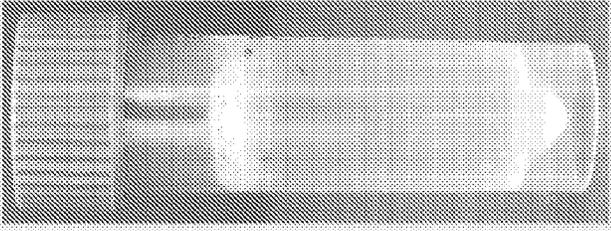
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	Some undissolved silk, cloudy, slightly viscous 	Very slight amount of silk undissolved, clear with darker color 	Some undissolved silk, highly viscous 	Small amount of undissolved silk, not too viscous 

Fig. 25A

Fig. 25B

Fig. 25C

Fig. 25D

Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
6 Hours	Slightly cloudy with some undissolved silk	Clear with darker color	Some undissolved silk, viscous	Darker color, some undissolved silk, slightly cloudy

Fig. 26A

Fig. 26B

Fig. 26C

Fig. 26D

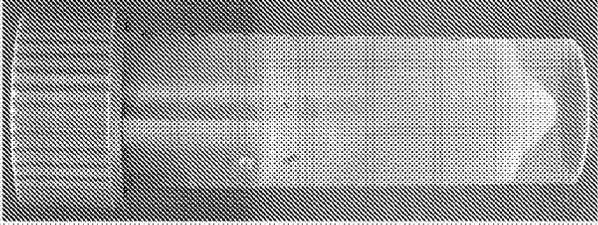
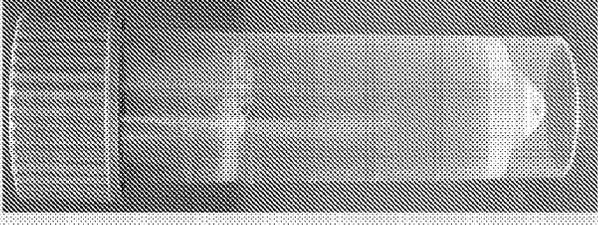
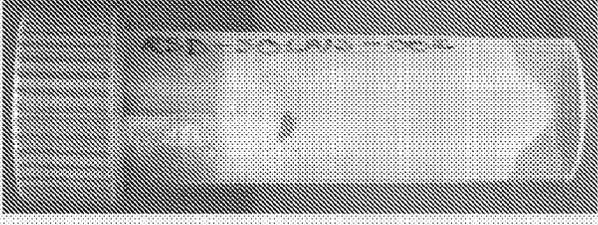
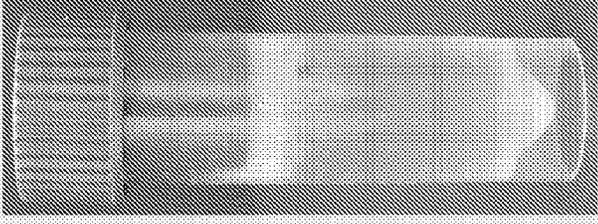
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
1 Hour	Somewhat cloudy with darker color, some silk particles	Completely clear with dark color, slight amount of silk particles	Cloudy, some undissolved silk, highly viscous	Small amount of undissolved silk, partially cloudy, darker color
				

Fig. 27A

Fig. 27B

Fig. 27C

Fig. 27D

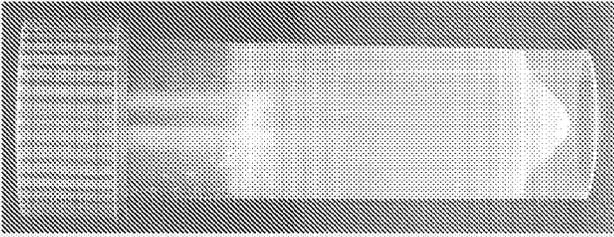
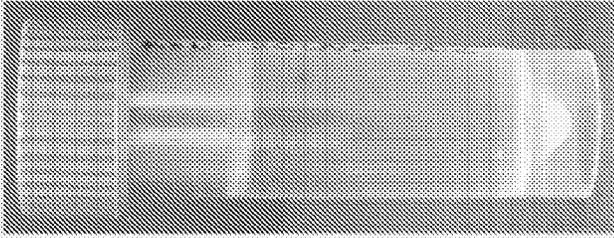
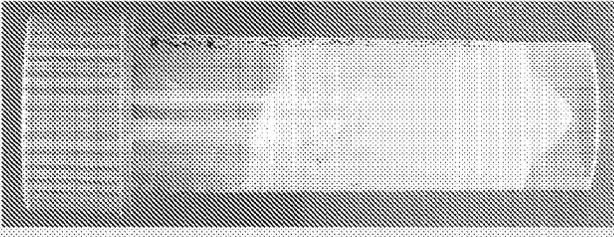
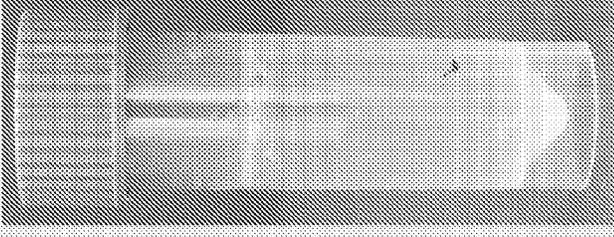
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	Small amount of undissolved silk, highly cloudy 	Little to no undissolved silk, deep auburn color 	Some undissolved silk, highly cloudy 	Slight amount of silk particles, dark color, less viscous 

Fig. 28A

Fig. 28B

Fig. 28C

Fig. 28D

Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
6 Hours	Slightly cloudy, slight amount of undissolved silk	No undissolved silk, completely clear, dark auburn	Cloudy, viscous, some undissolved silk	Slight amount of undissolved silk, slightly cloudy

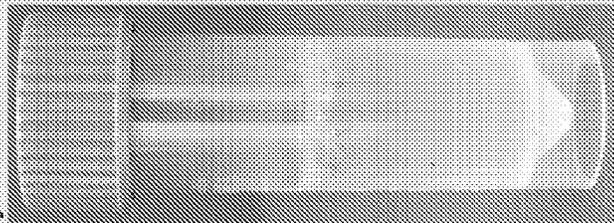
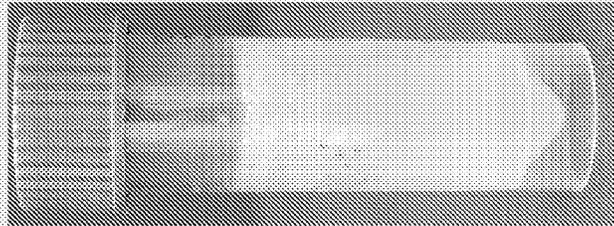
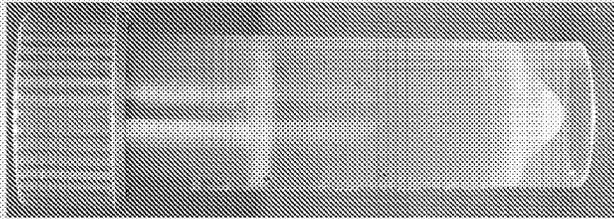
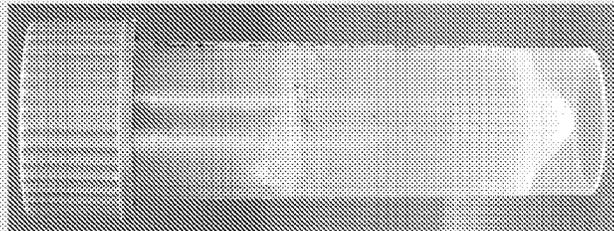


Fig. 29A

Fig. 29B

Fig. 29C

Fig. 29D

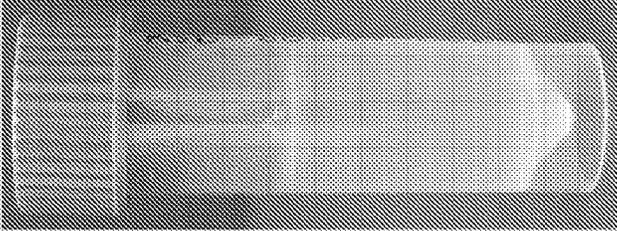
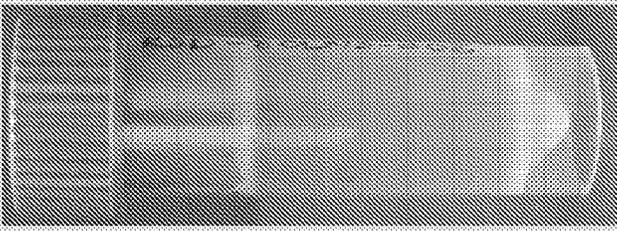
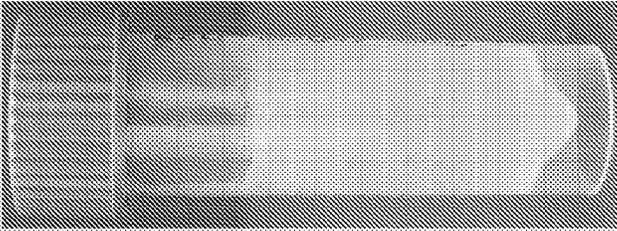
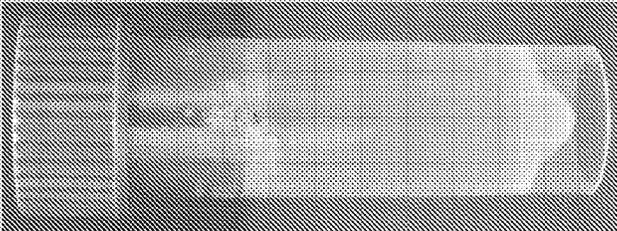
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
1 Hour	All silk dissolved, cloudy 	All silk dissolved, clear 	All silk dissolved, viscous, cloudy 	All silk dissolved, viscous, cloudy 

Fig. 30A

Fig. 30B

Fig. 30C

Fig. 30D

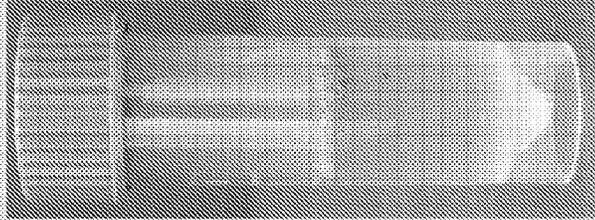
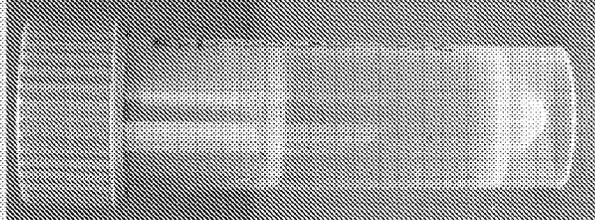
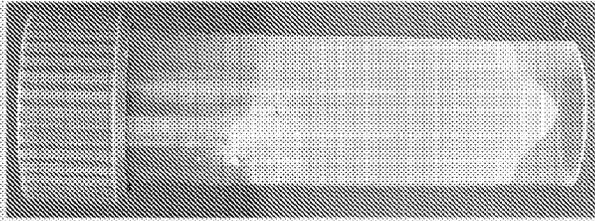
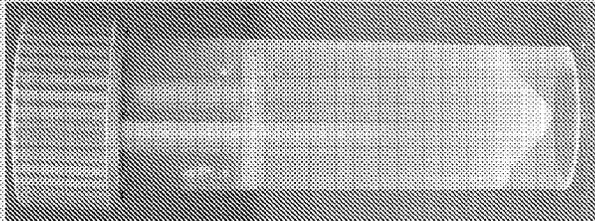
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
4 Hours	All silk dissolved, slightly cloudy but mostly clear 	All silk dissolved, clear, dark 	All silk dissolved, cloudy 	All silk dissolved, cloudy 

Fig. 31A

Fig. 31B

Fig. 31C

Fig. 31D

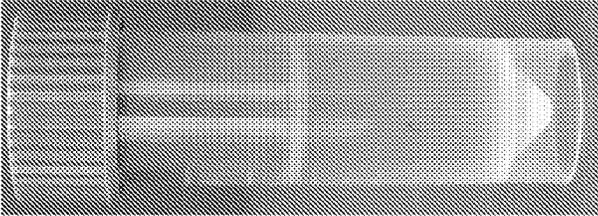
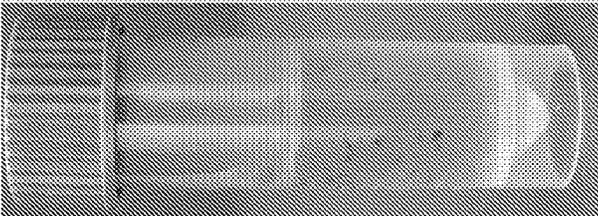
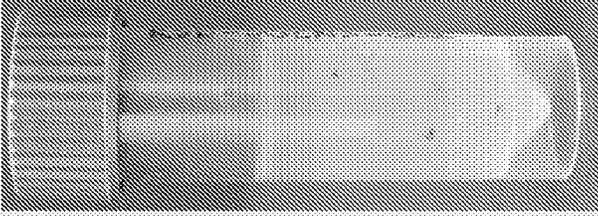
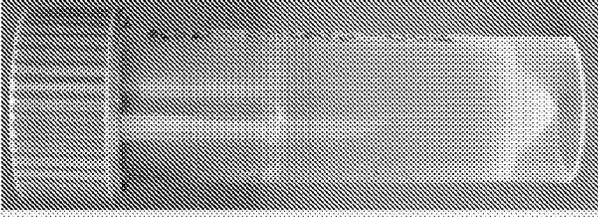
Time Point	Sericin was extracted at 100° C, 30 min	Sericin was extracted at 100° C, 60 min	Sericin was extracted at 90° C, 30 min	Sericin was extracted at 90° C, 60 min
6 Hours	All silk dissolved, cloudy 	All silk dissolved, clear 	All silk dissolved, cloudy 	All silk dissolved, only slightly cloudy 

Fig. 32A

Fig. 32B

Fig. 32C

Fig. 32D

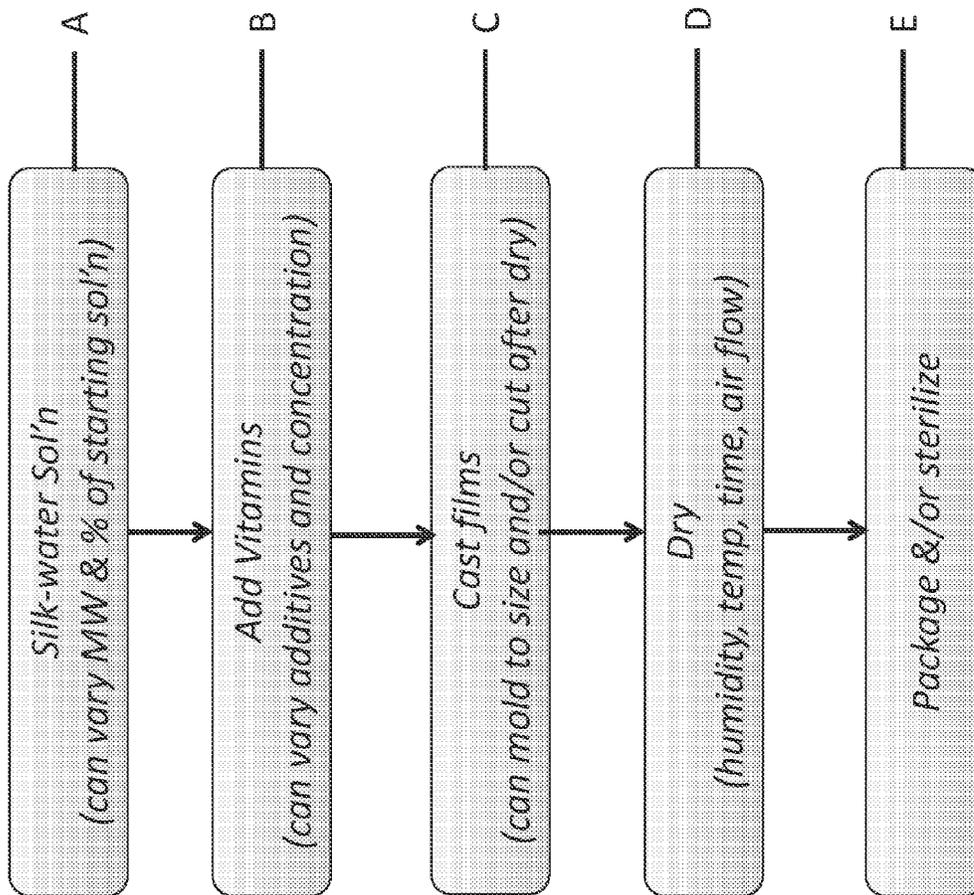


Fig. 33

Methods for Silk Film Drying Study

- Diluted silk solution to 2% (m/v%) silk concentration
- Vitamin C added in 5:1 silk:VitC ratio

Film Casting

- Cast 15 samples for each set with 1.85 mL of solution pipetted onto a 1" diameter silicone mold
- Films were cast in drying location and were not moved until testing

Observations and Testing

- Films were observed and massed at 1, 2, 3, 4, 5, 6, 7, 8, 12, 24, and 48 hours after casting
- Tested 5 films from each set at 1, 8, and 48 hours after casting
- Testing procedure consisted of massing, photographing and dissolution of films

Fig. 34

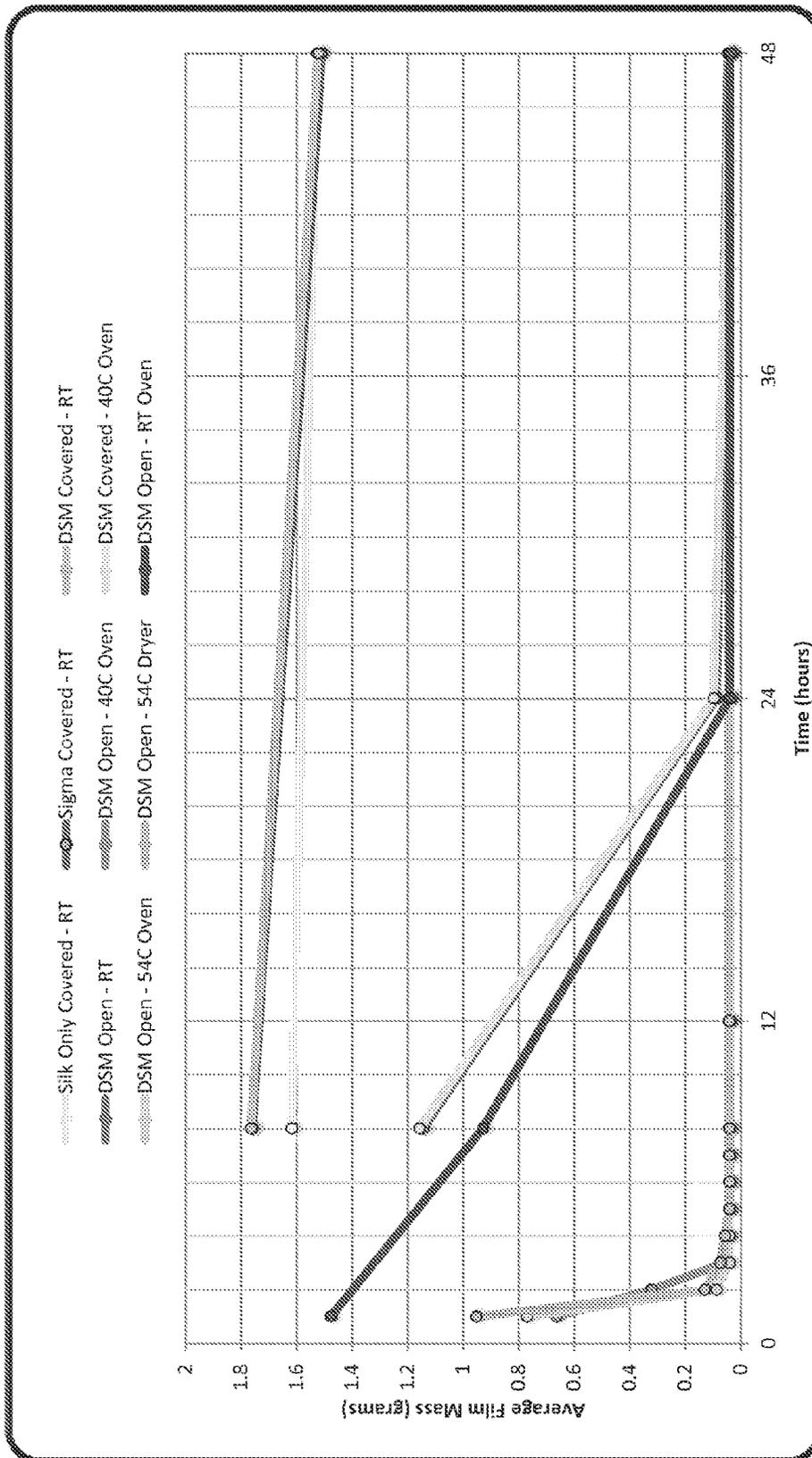


Fig. 35

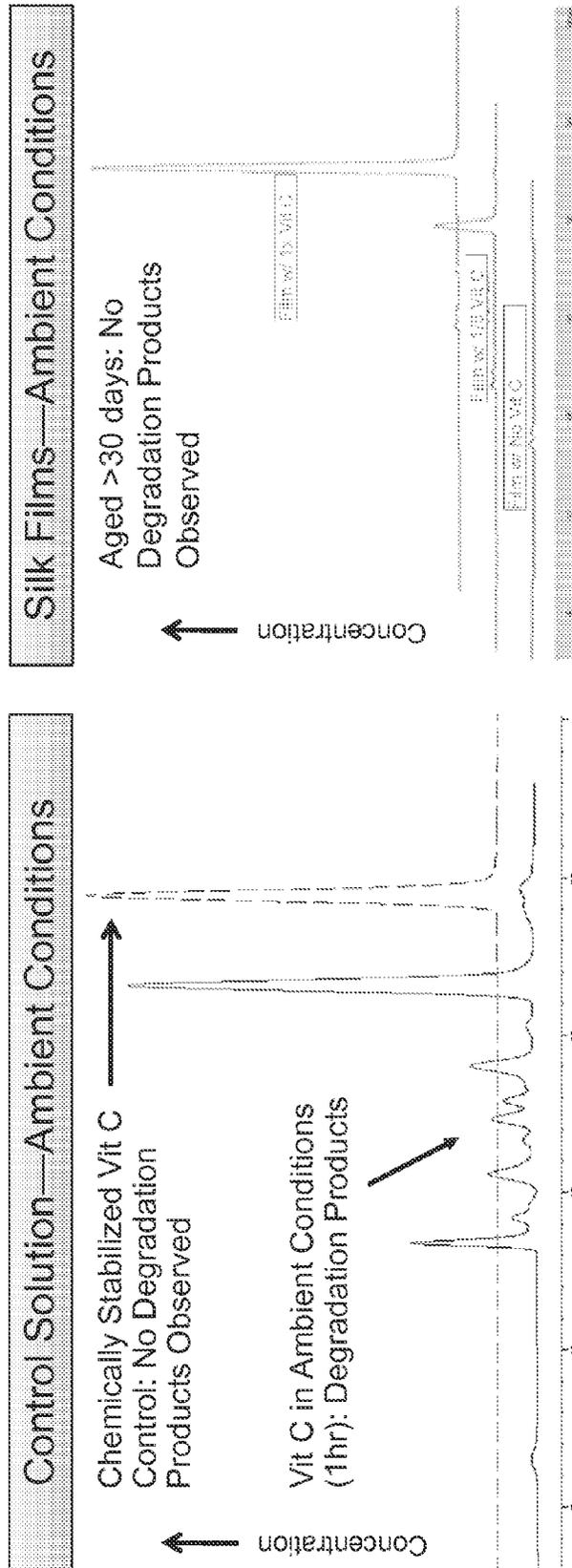
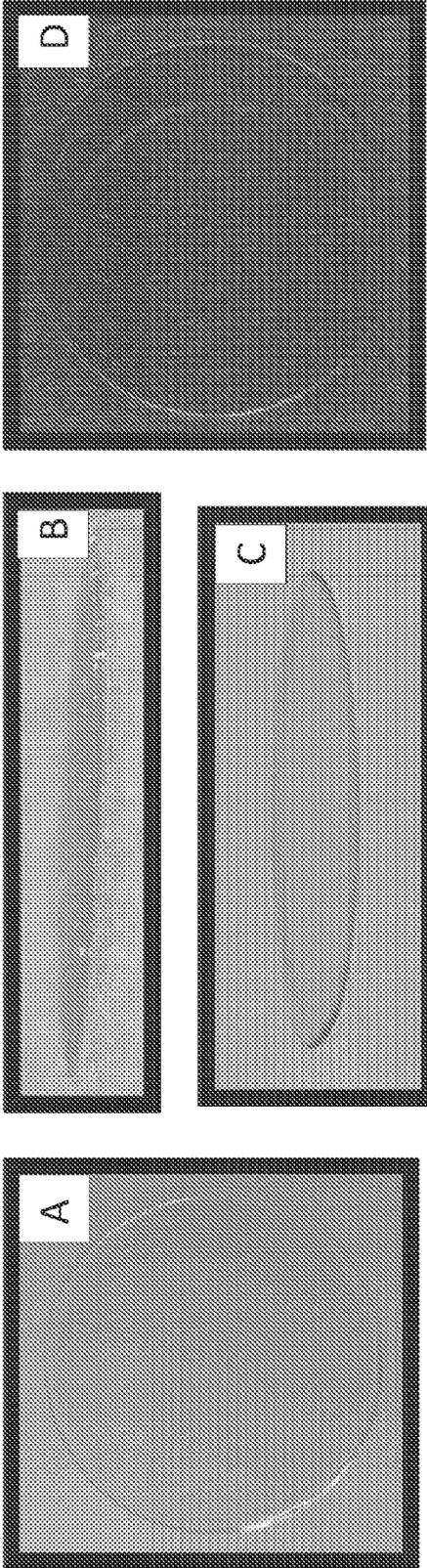
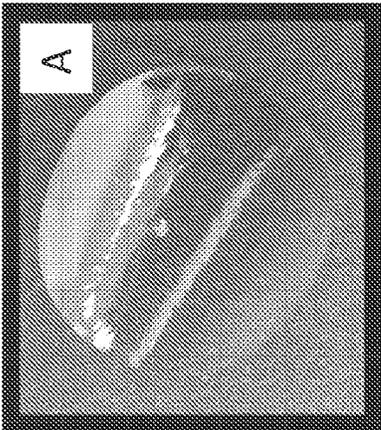
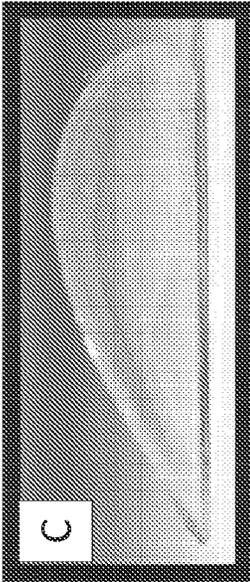
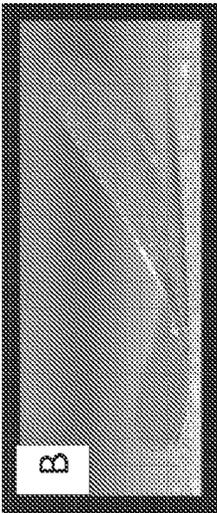
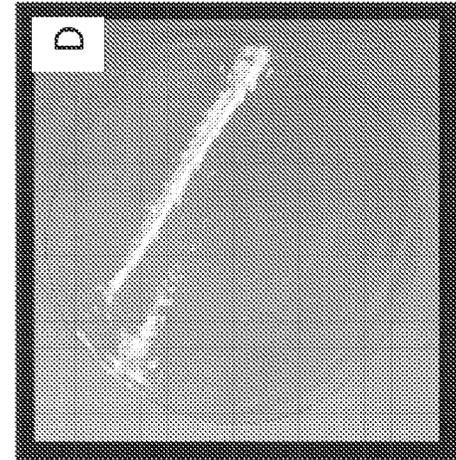


Fig. 36B

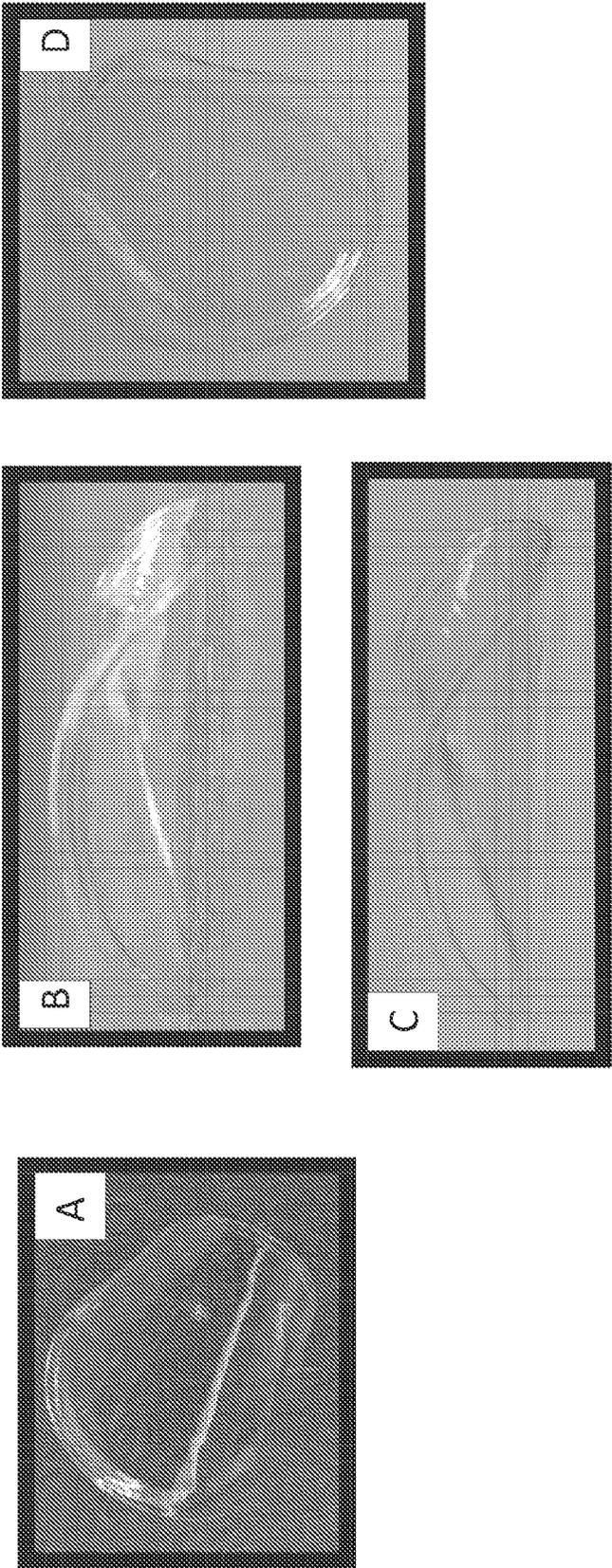
Fig. 36A



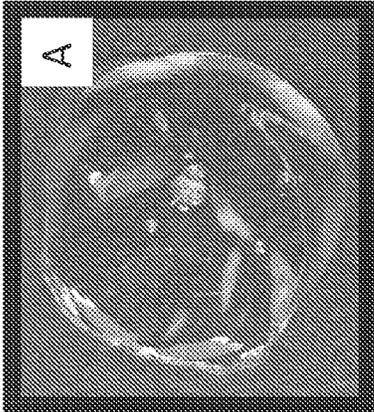
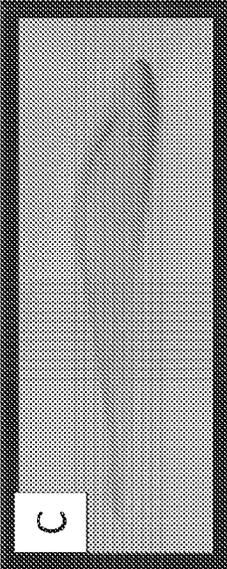
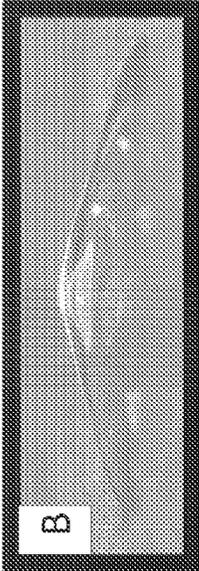
Figs. 37A-37D



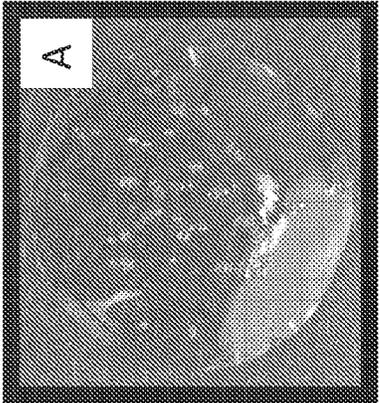
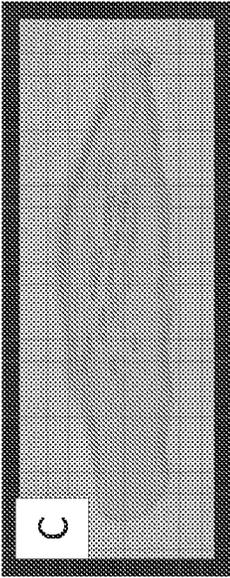
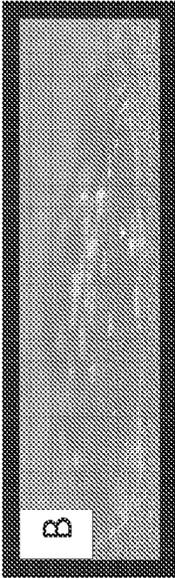
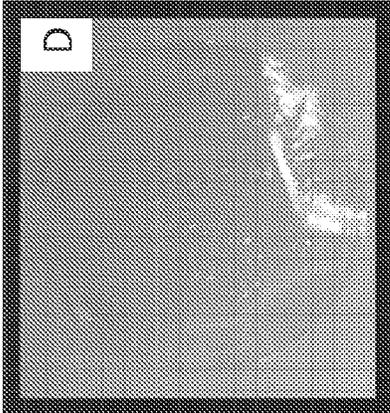
Figs. 38A-38D



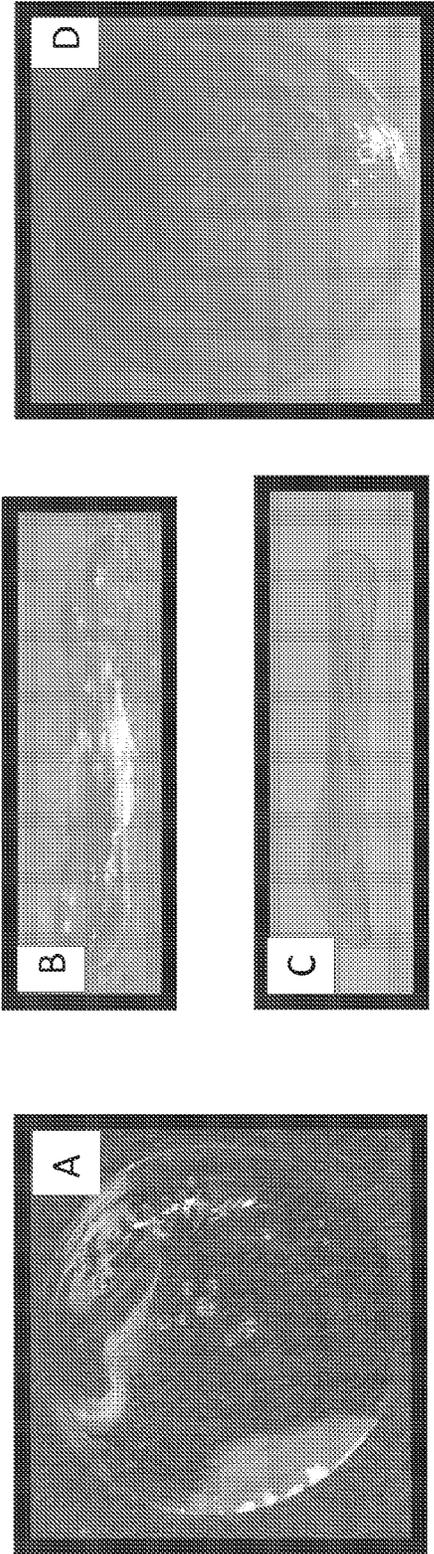
Figs. 39A-39D



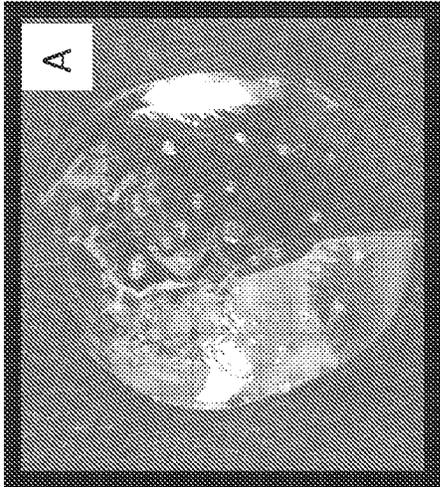
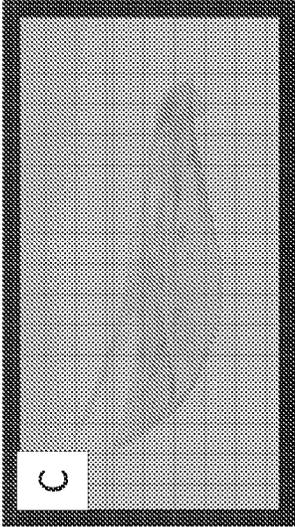
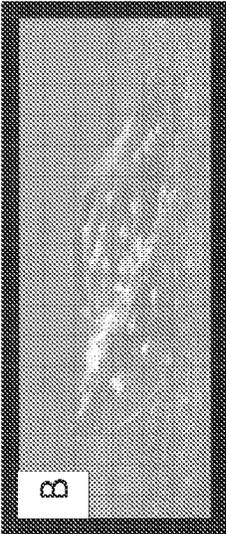
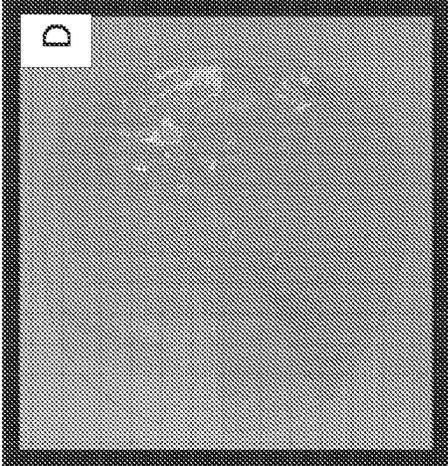
Figs. 40A-40D



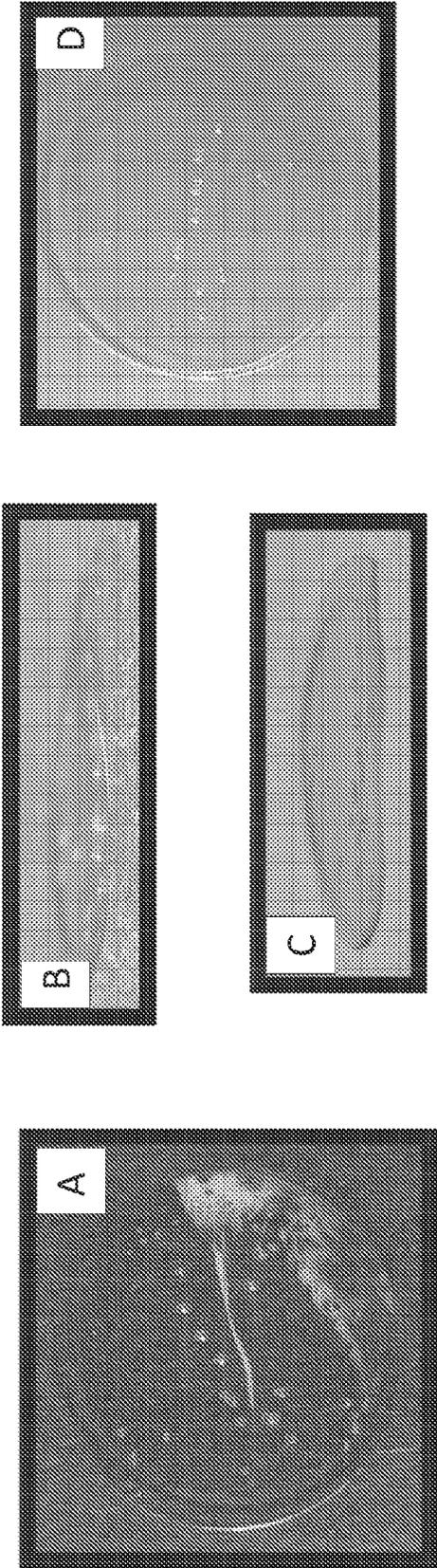
Figs. 41A-41D



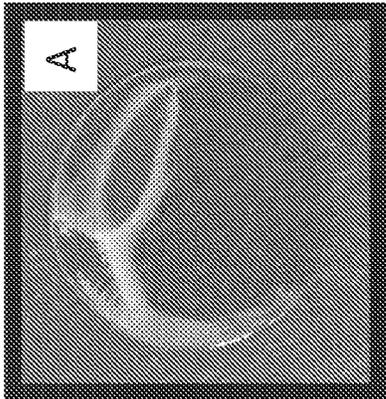
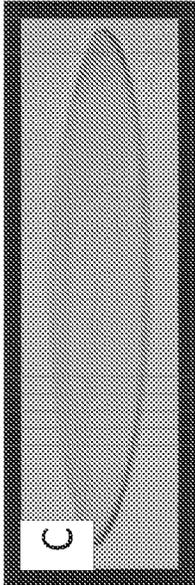
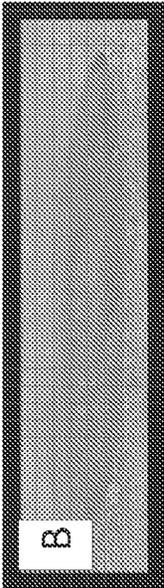
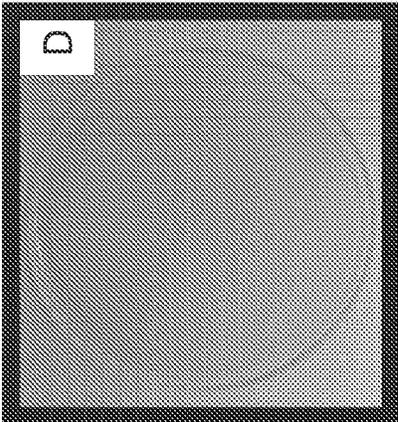
Figs. 42A-42D



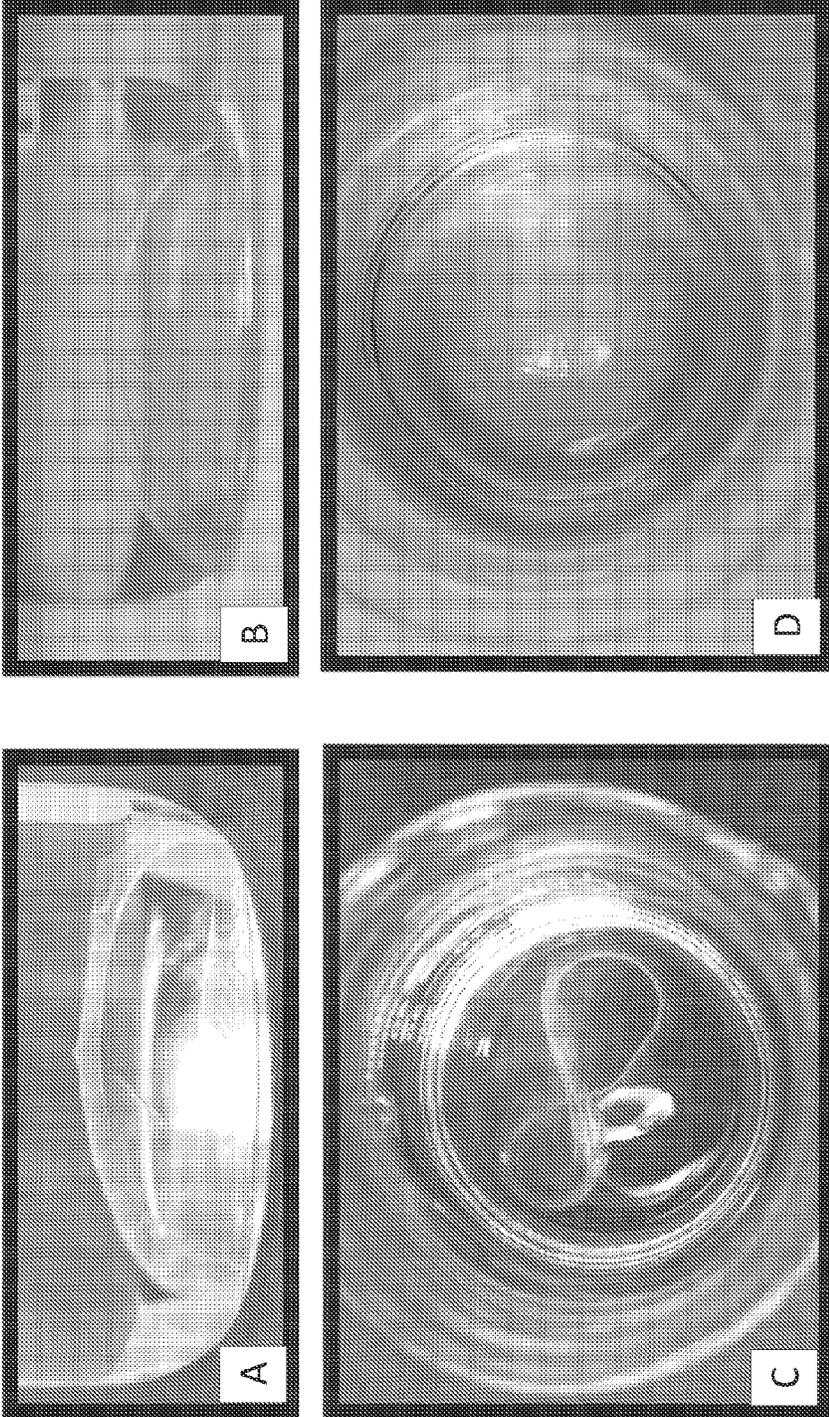
Figs. 43A-43D



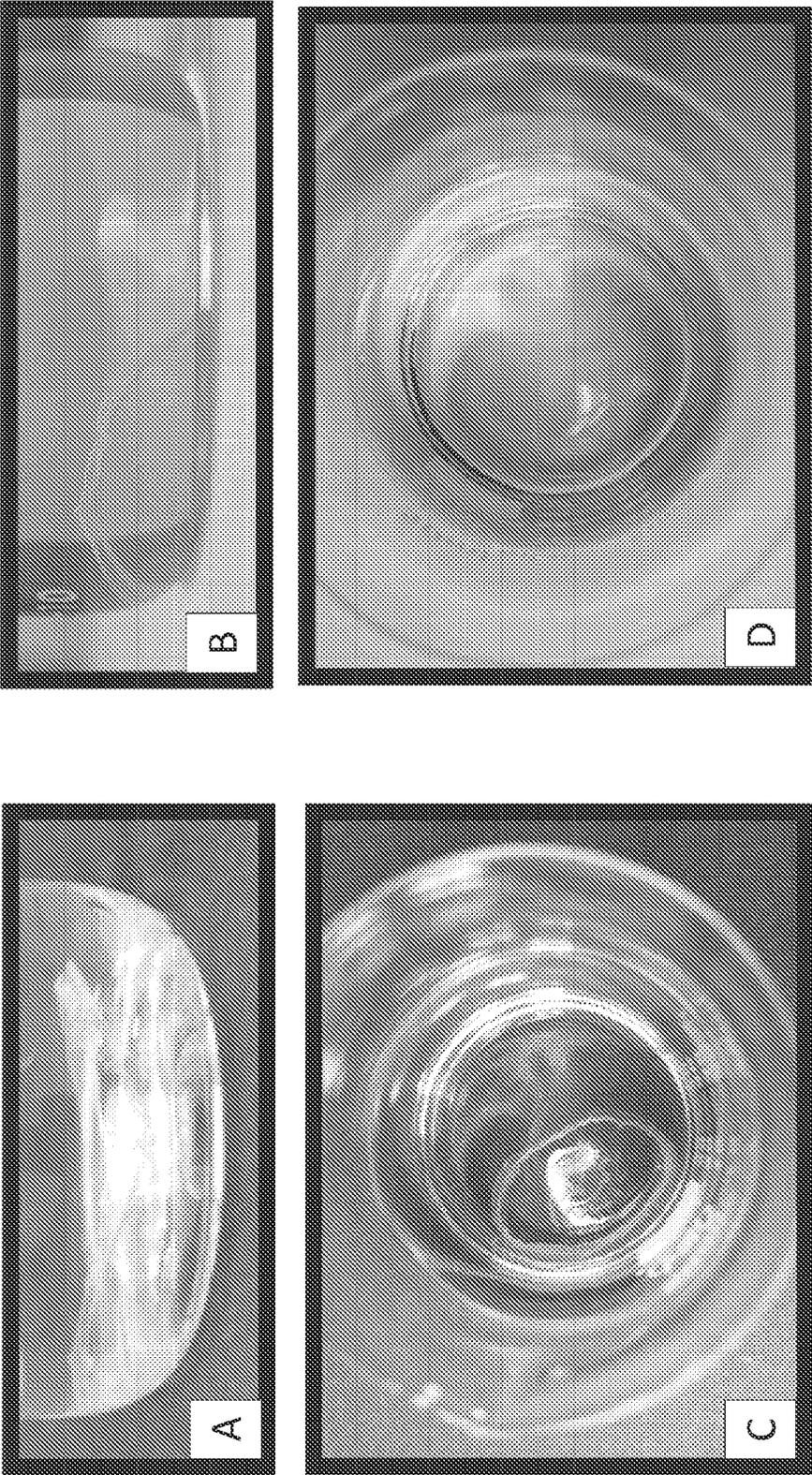
Figs. 44A-44D



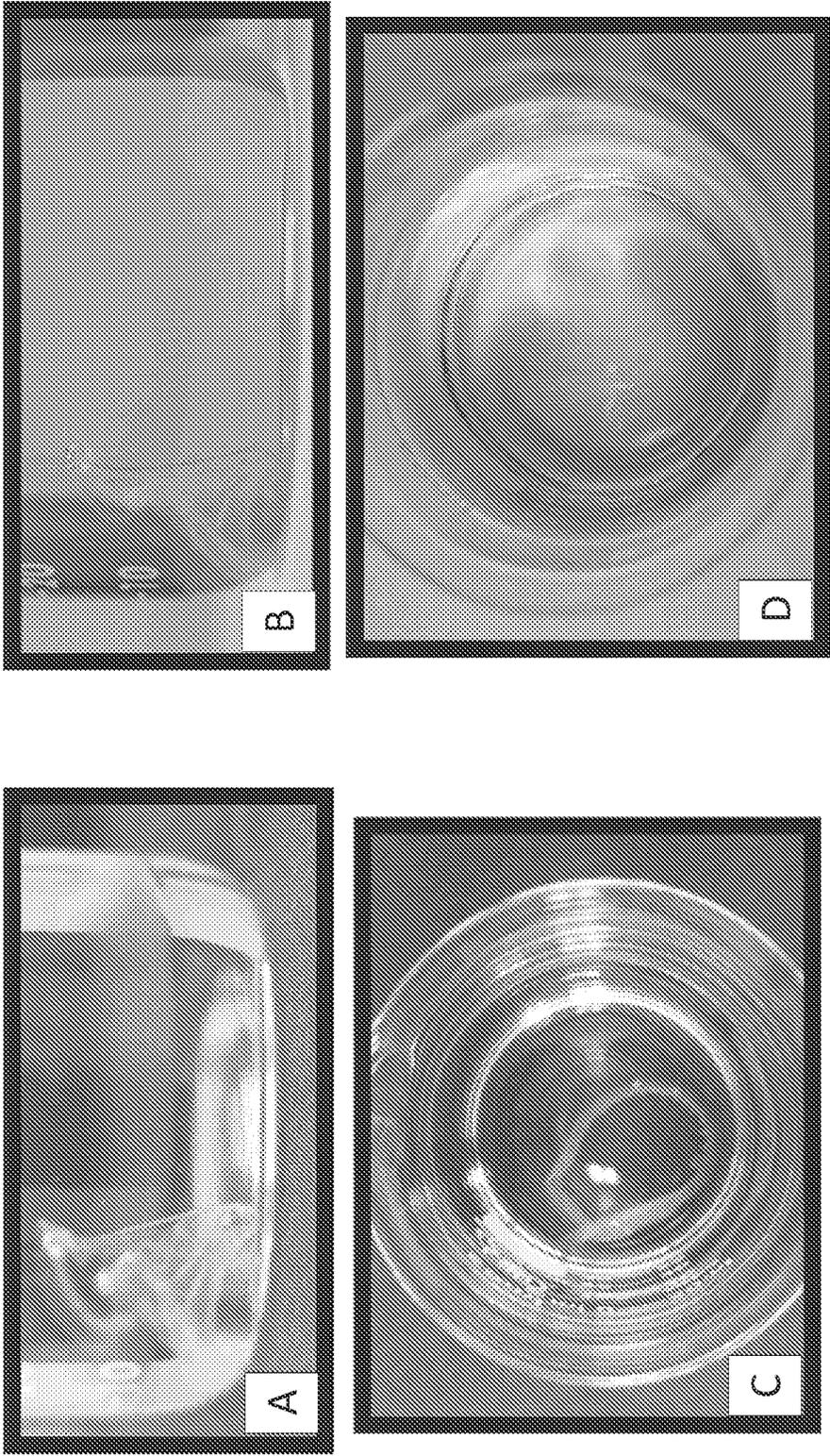
Figs. 45A-45D



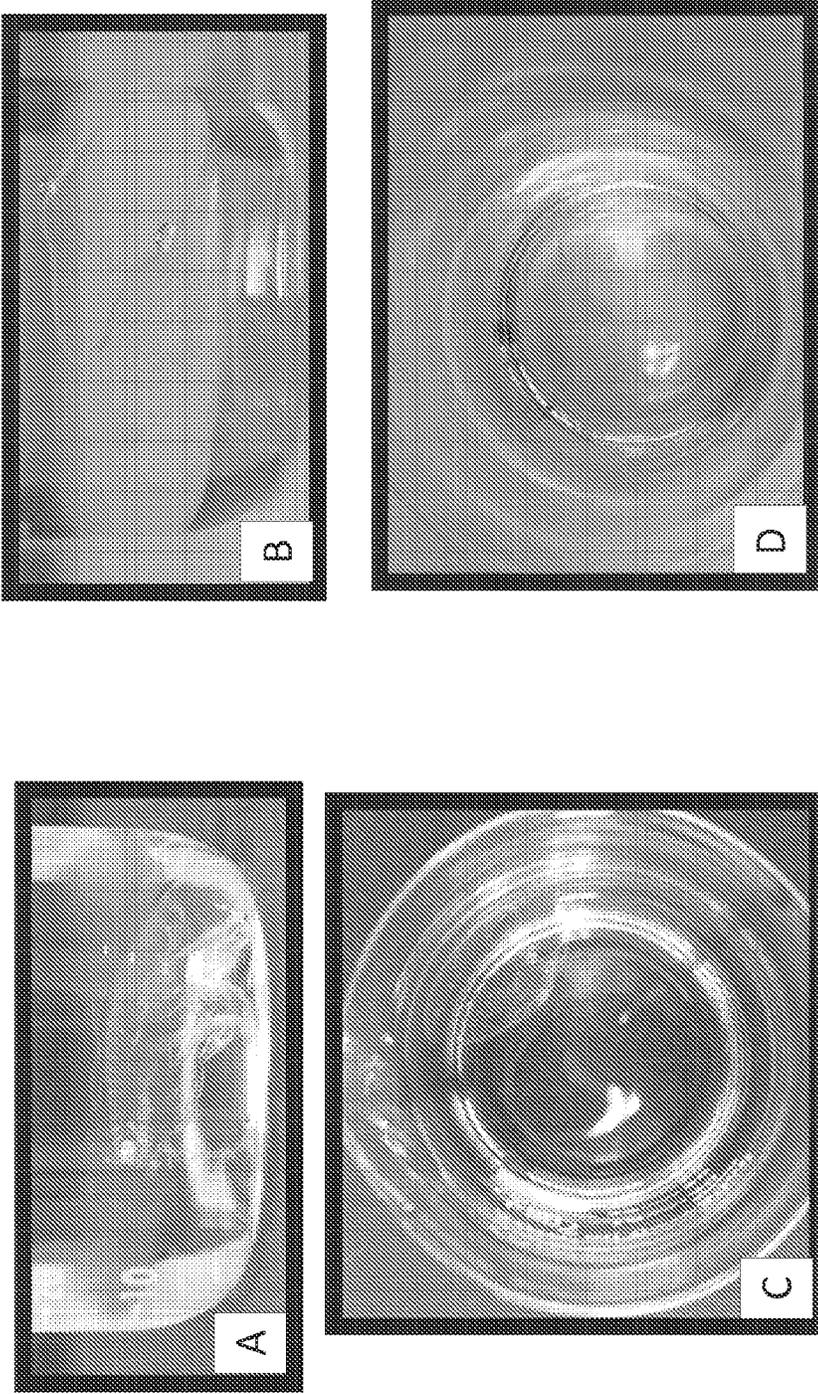
Figs. 46A-46D



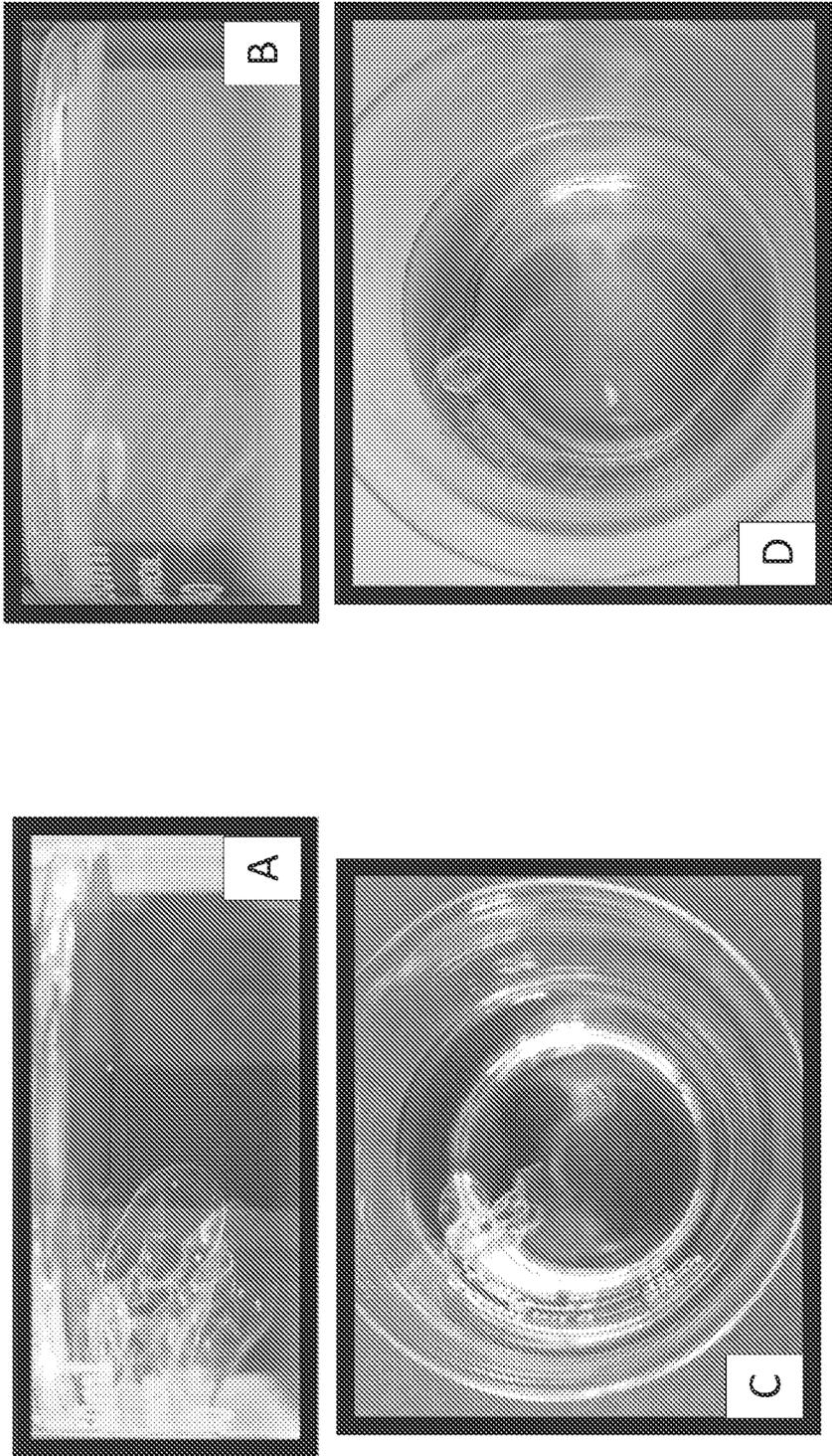
Figs. 47A-47D



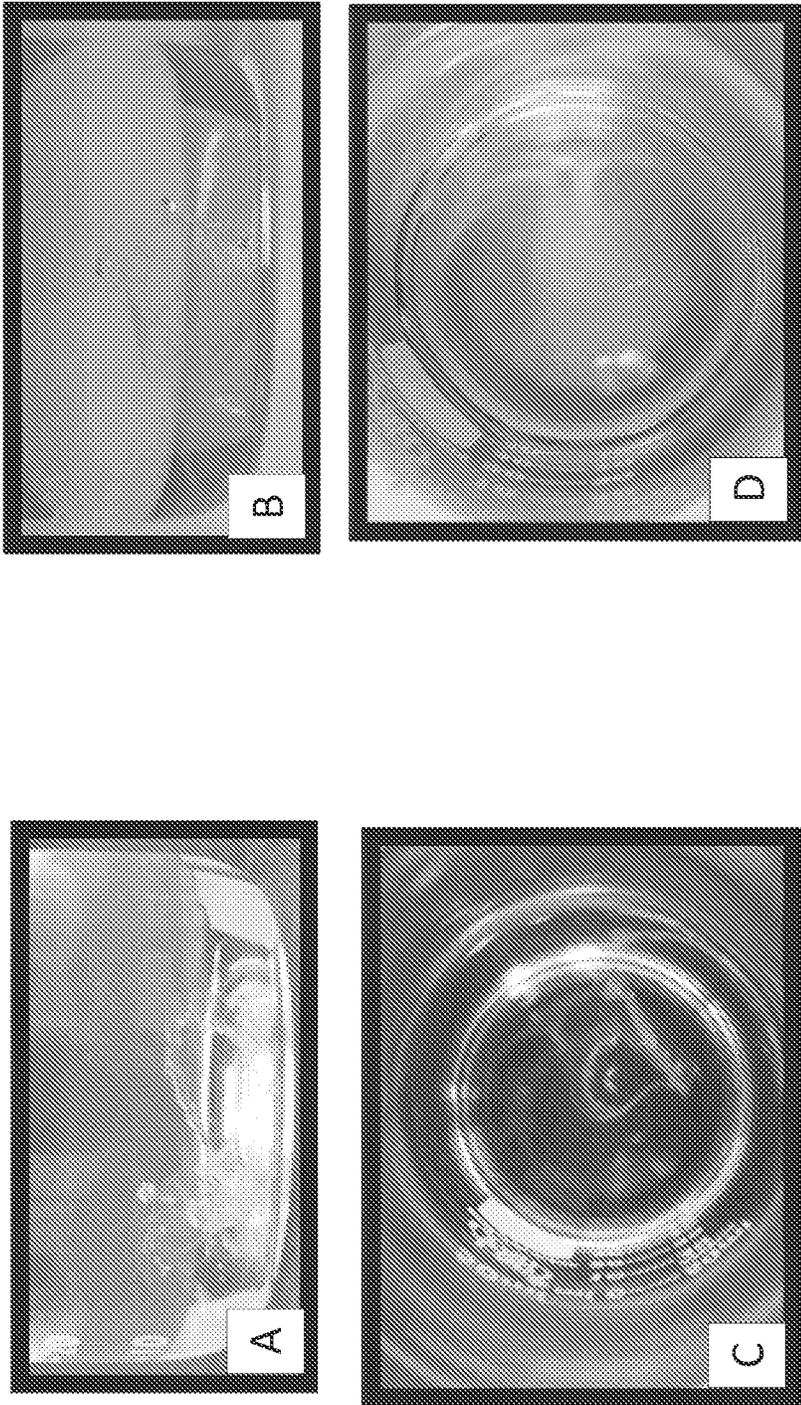
Figs. 48A-48D



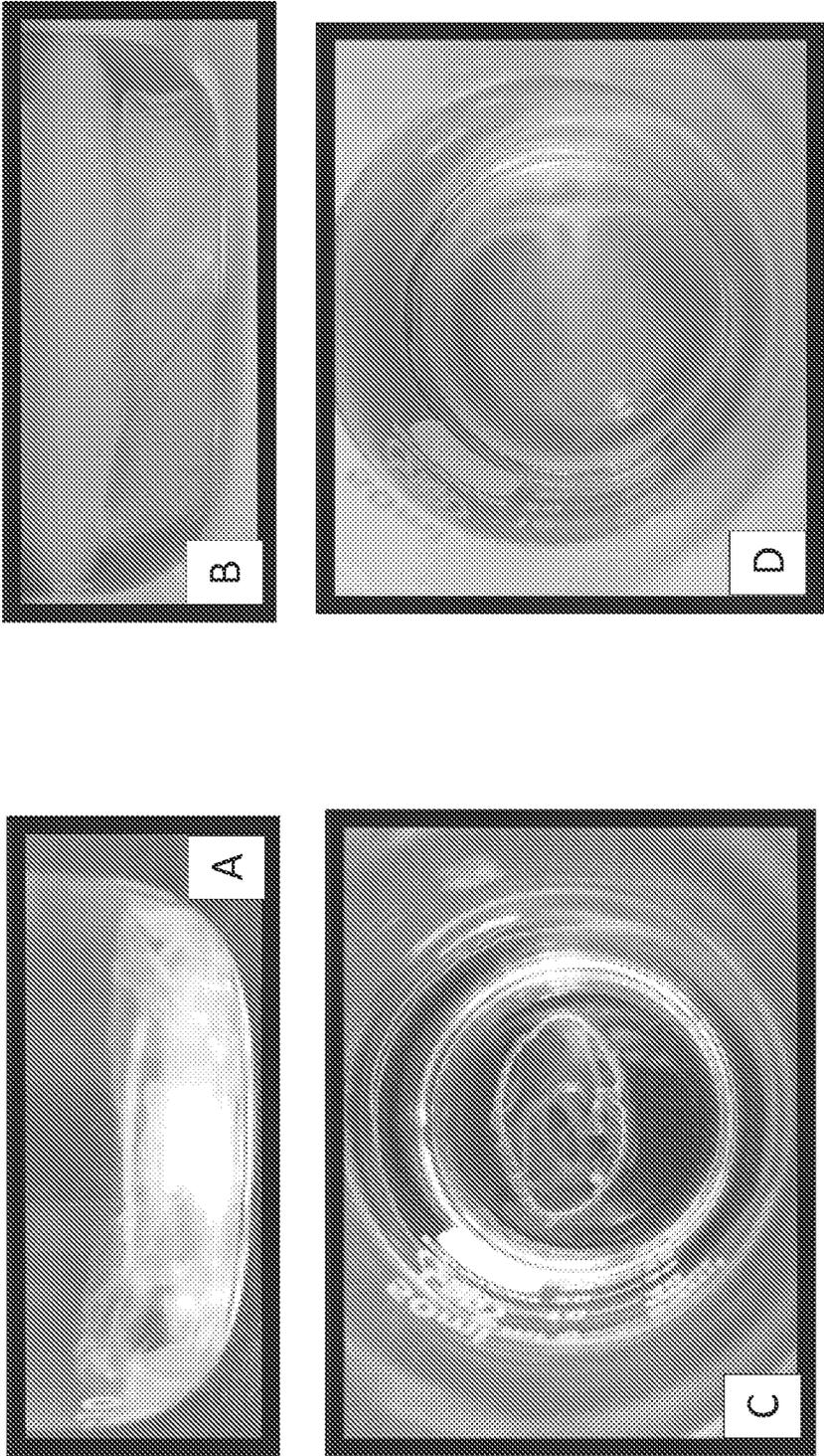
Figs. 49A-49D



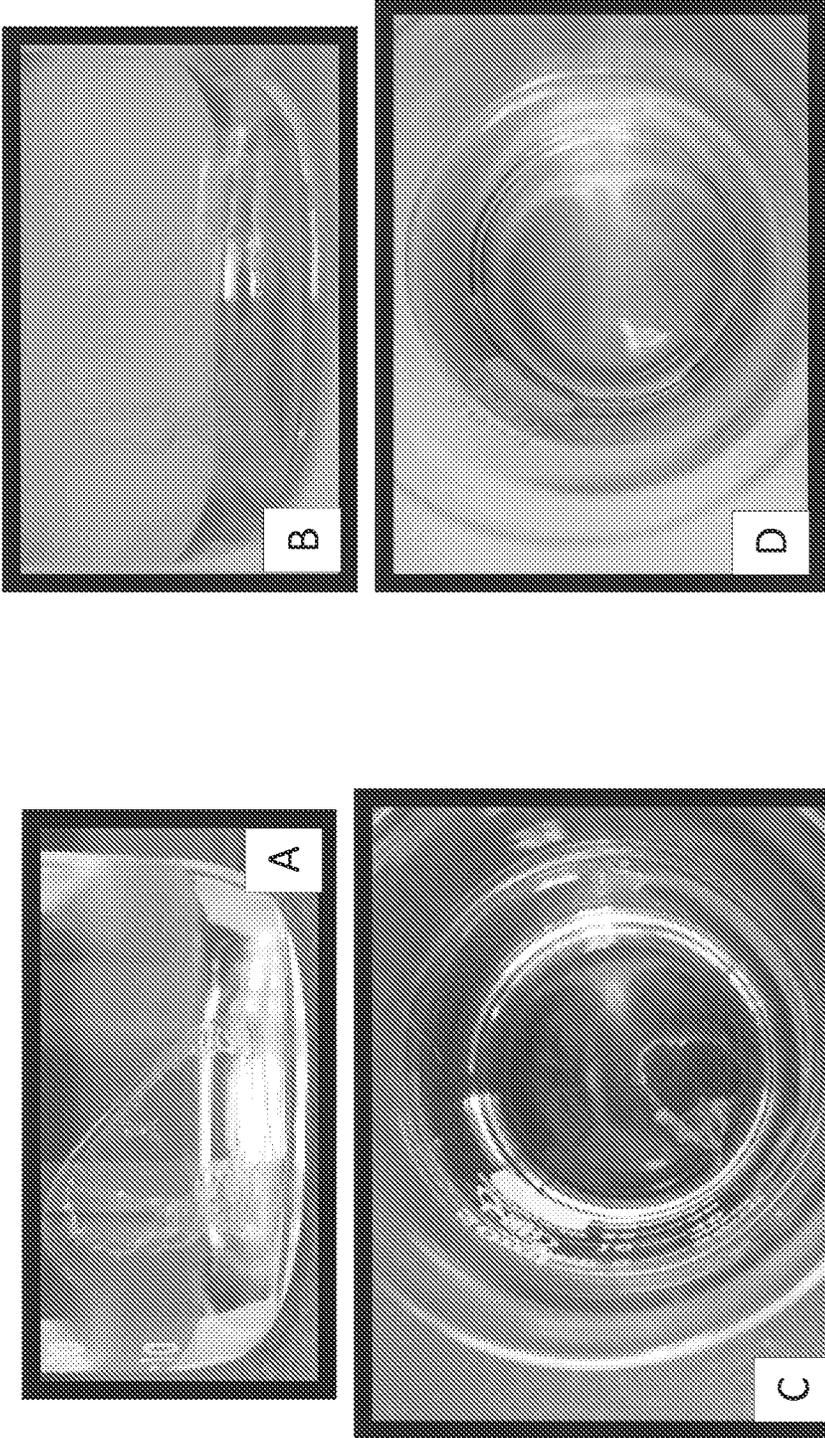
Figs. 50A-50D



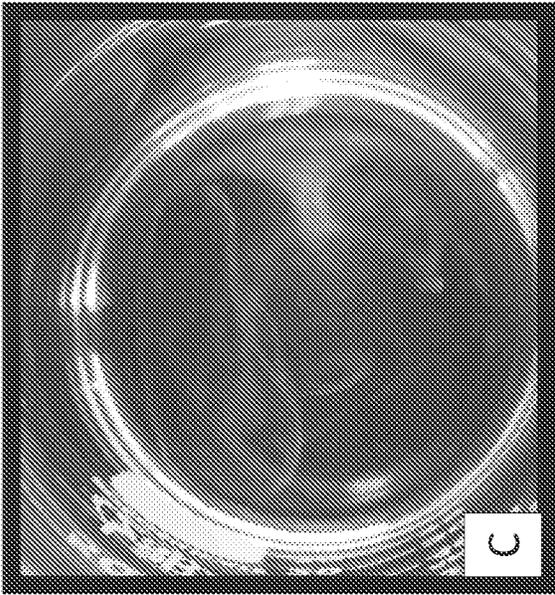
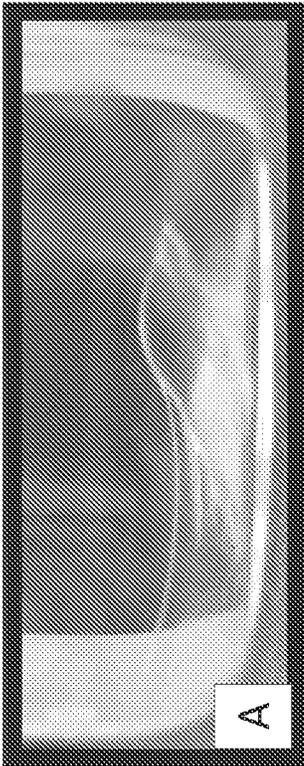
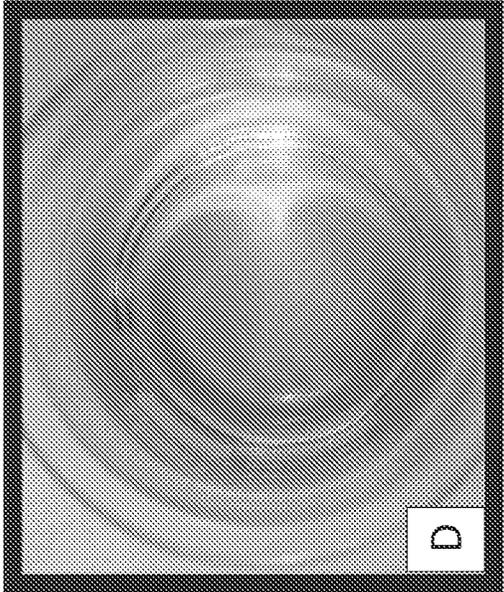
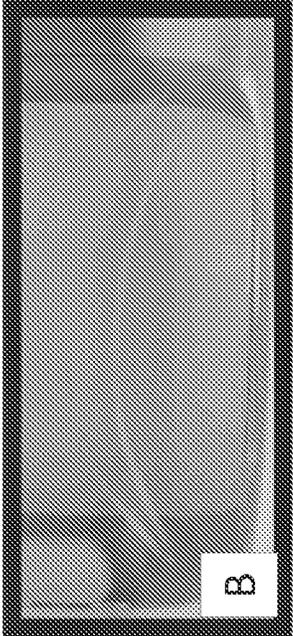
Figs. 51A-51D



Figs. 52A-52D



Figs. 53A-53D



Figs. 54A-54D

Lithium Bromide and Sodium Carbonate Concentration in Silk Protein Solution

Sample ID	Sample Description	Average Concentration of Na ₂ CO ₃ (ppm)	Average Concentration of LiBr (ppm)
A	TFF 5kDa	32.13	90.85
B	TFF 10 kDa	42.91	107
C	TFF 10 kDa	49.06	78.55
D	STI 1(TFF-10-0019)	2.17	129.07
E	STI 2(TFF-10-0033)	2.63	196.2
F	STI 3(TFF-10-0034)	4.18	248.93

Method: 100C extraction for 60 min, 60C rinse, 100C LiBr in 100C oven for 60 min.
Note that TFF could be run for longer and/or at different flow rates (as varied between A-C and D-F) to alter ppm of Na₂CO₃ and LiBr.

Fig. 55

Sodium Carbonate in Silk Protein Formulations

Sample ID	Details	Sample Weight (mg)	Conc. of Na ₂ CO ₃ in Original Film		Std. Dev	Error %
			Average (mg/Film)			
A	Blank Film	ND	NA	NA	NA	NA
B	1:1 film	30.1	0.0141	0.0008	5.55%	
C	5:1 film	17.3	0.0127	0.0006	4.69%	

Method: 100C extraction for 20 min, RT rinse, LiBr in 60C oven for 4-6 hours. 2% silk films air dried at RT

Fig. 56

Lithium Bromide in Silk Protein Formulations

Sample ID	Details	Sample Weight (mg)	Conc. of LiBr in Original Film		Error %
			Average (mg/Film)	Std. Dev	
A	Blank Film	ND	NA	NA	NA
B	1:1 film	30.1	0.0363	0.0042	11.47%
C	5:1 film	17.3	0.0259	0.0005	1.82%

Method: 100C extraction for 20 min, RT rinse, LiBr in 60C oven for 4-6 hours.
2% silk films air dried at RT

Fig. 57

Lithium Bromide and Sodium Carbonate content in Silk Protein Solution

Sample ID	Solution Volume Equivalent to (X) Films	Sample Weight (mg)	Concentration	
			Na ₂ CO ₃	LiBr
1	6	0.171	ND	ND
2	8	0.228	ND	ND
3	10	0.285	ND	ND
4	12	0.342	ND	ND
5	Neat	-	ND	ND

*ND=None Detected

Method: 100C boil for 60 min, 60C rinse, LiBr in 60C oven for 4-6 hours

Fig. 58

Vitamin C in Silk Protein Formulations

Sample ID	Description (Silk:Vit C)	Sample Weight (mg)	Conc. of Vitamin C		Std. Dev	Error %
			Average (mg/Film)			
A	Blank Film	4.2	0		0	0.00%
B1	1:1 film	7.8	3.0974		0.0538	1.74%
B2	1:1 film	7.7	3.2534		0.0312	0.96%
C1	5:1 film	4.9	0.6194		0.0096	1.54%
C2	5:1 film	4.9	0.6454		0.0061	0.94%

Method: 100C extraction for 20 min, RT rinse, LiBr in 60C oven for 4-6 hours.
2% silk films air dried at RT

Fig. 59

Stability of Vitamin C in Solution

Sample ID	Time (hour)	Actual Conc. (µg/mL)	Area	Concentration Vit C (µg/mL)	Recovered (%)	Stability (%) After 24 hrs.
A	0	82.4	4277.9	80.53	97.73	
B	26	82.4	4088.94	77.62	94.2	
Average =			4183.42	79.07	95.96	96.39
Std. Dev. =			133.62	2.06	2.49	
% Error			3%	3%	3%	

Method: Vitamin C solution (no silk)

Fig. 60

Molecular Weights of Silk Protein Solutions

Sample ID	Sample Description	Mn	Mw	Polydispersity (PD) (Mw/Mn)
A	TFF 5kDa	14,497	33,874	2.3366
B	TFF 10 kDa	14,542	33,455	2.3006
C	TFF 10 kDa	14,972	34,026	2.2726
D	Silk protein solution in water	12,055	26,531	2.2008

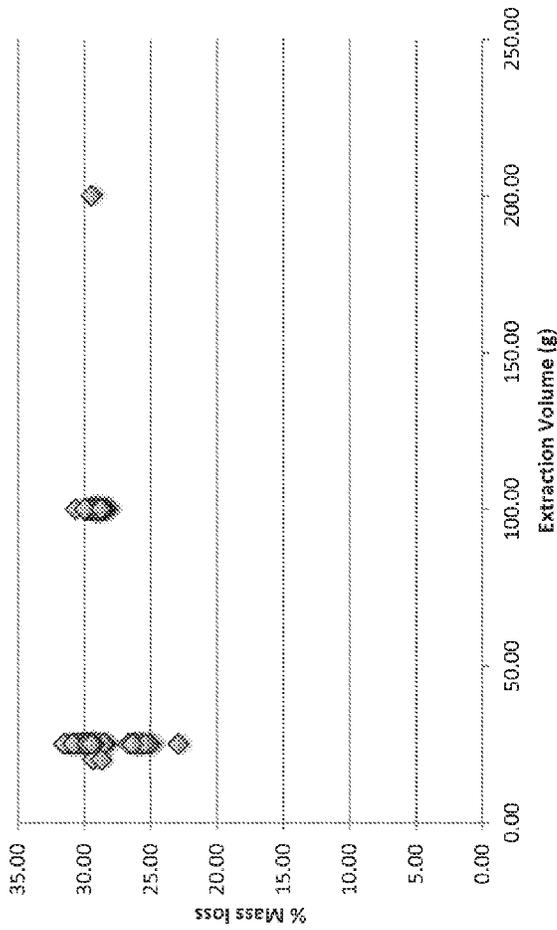
Method:

TFF: 100C extraction for 60 min, 60C rinse, 100C LiBr in 100C oven for 60 min.

Silk Protein: 100C extraction for 20 min, RT rinse, LiBr in 60C oven for 4-6 hours

Fig. 61

Fig. 62A



Extraction Volume vs % Mass Loss

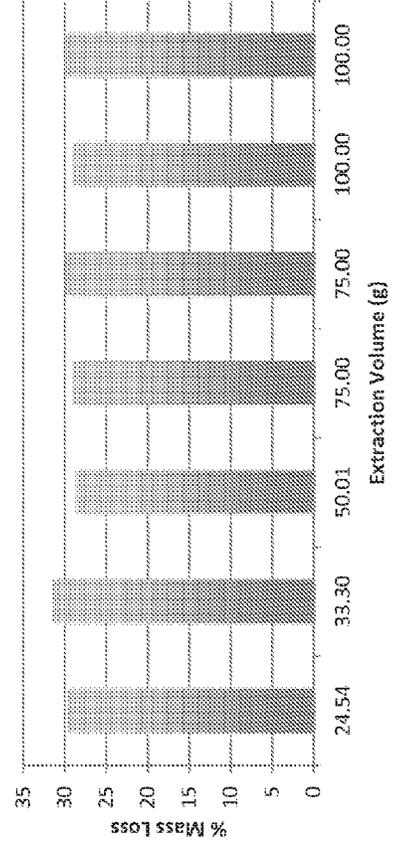


Fig. 62B

Sample	LiBr (M)	Avg MW	PD
STI 1(TFF-10-0019)	9.3	15727	2.033
STI 2(TFF-10-0033)	9.3	24587	2.3669
STI 3(TFF-10-0034)	9.3	25273	2.338
STI 9.3 M avg		21862	2.25
STI 1(TFF-10-0031)	~7.5	29645	3.0868
STI 2(TFF-10-0030)	~7.5	26856	2.9748
STI 7.5M avg		28250.5	3.0308

- * TFF-10-0019 from 2 25g extraction/35g dissolution
- * TFF-10-0034 from 100g extraction/ 17-35 g dissolution
- * TFF-10-0033 from 100g extraction/ 100 g dissolution

Fig. 63

30 min vs 60 min: 100C Boil, 100C LiBr, 100C oven

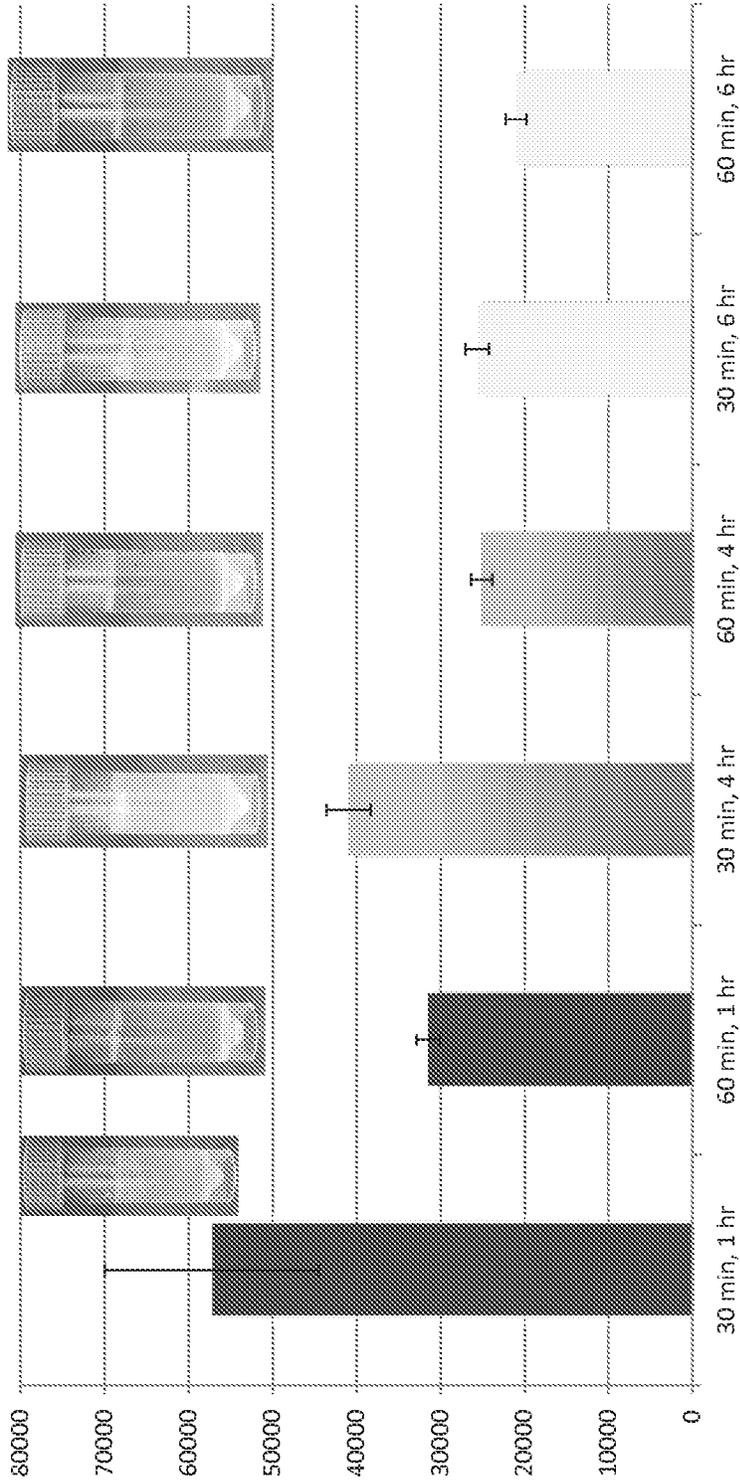


Fig. 64

30 min vs 60 min: 100C Boil, Boil LiBr, 60C Oven

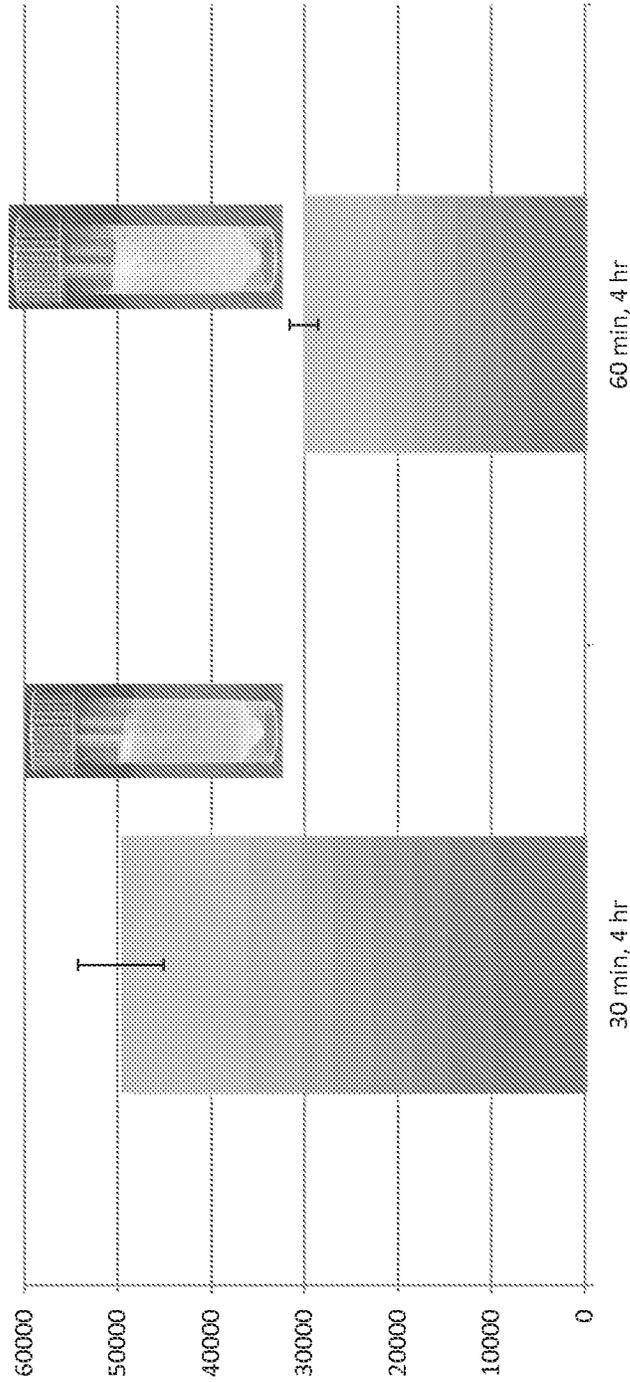


Fig. 65

30 min vs 60 min: 100C Boil, 60C LiBr, 60C oven

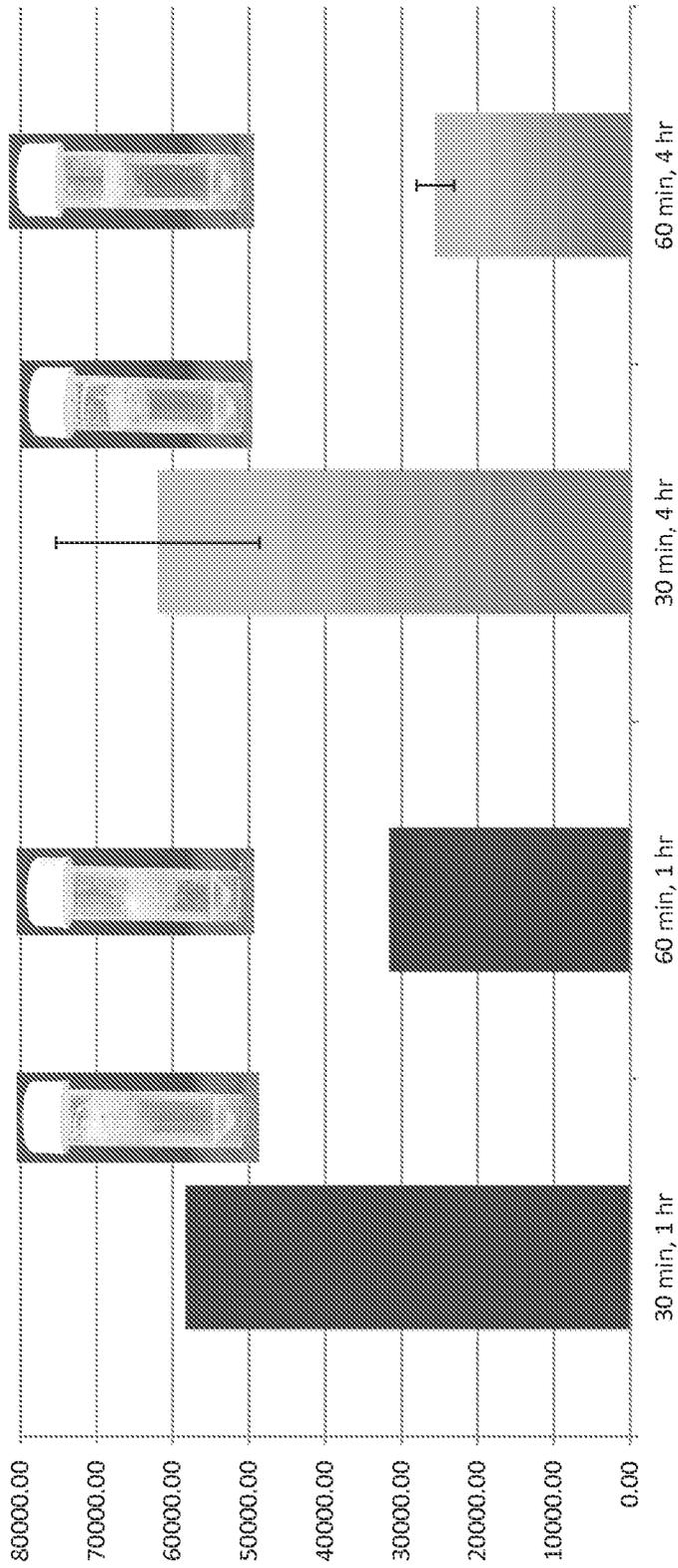


Fig. 66

30 min vs 60 min: 100C Boil, 80C LiBr, 80C oven

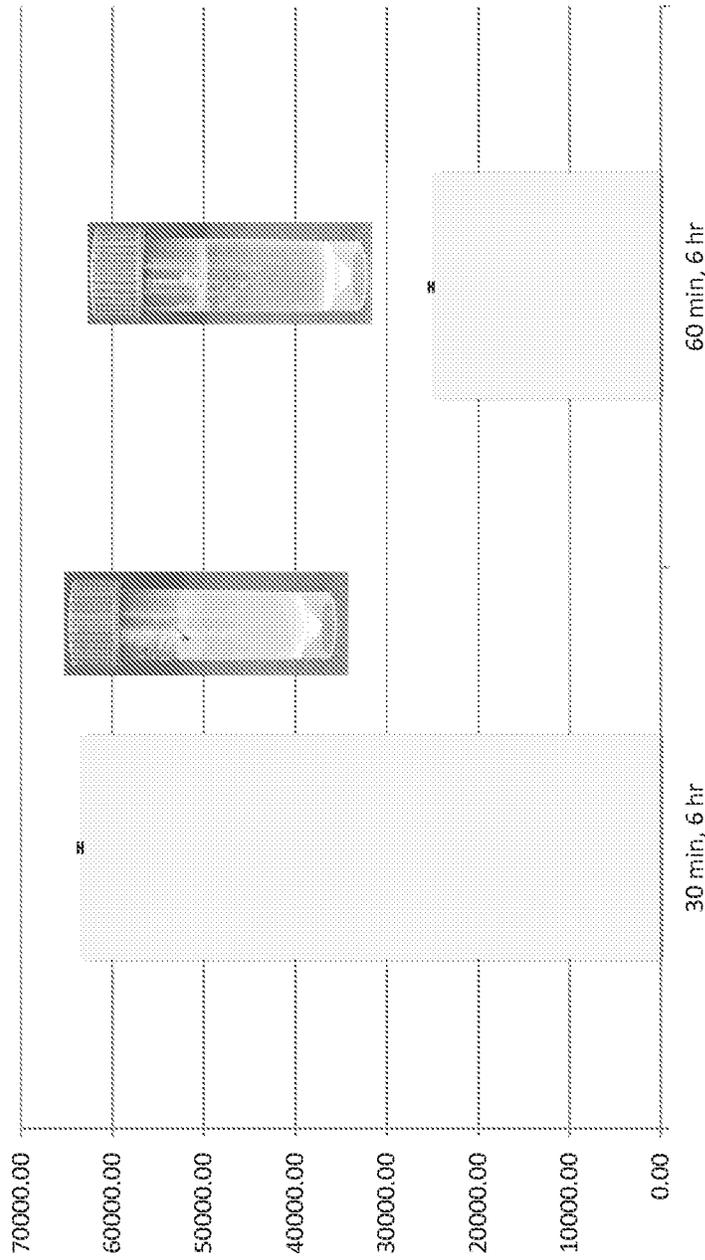


Fig. 67

30 min vs 60 min: 100C Boil, 80C LiBr, 60C Oven

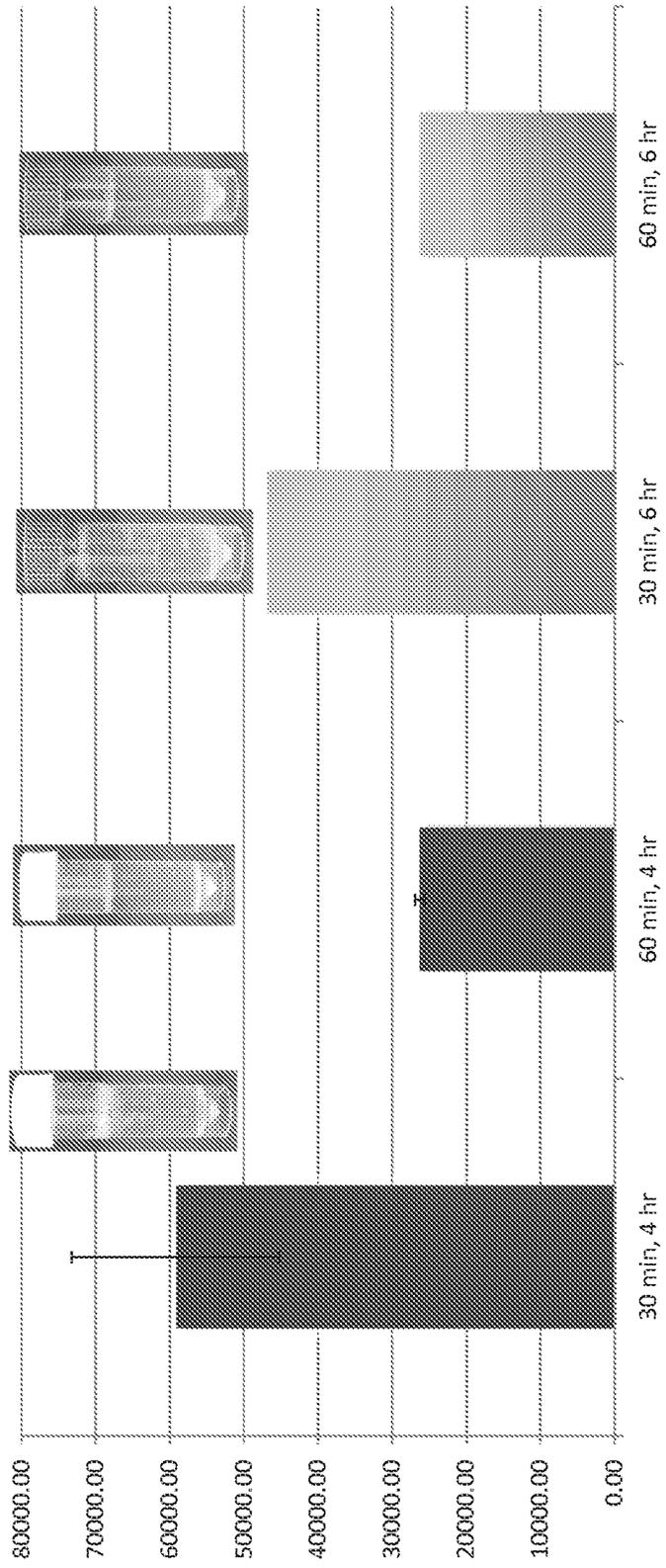


Fig. 68

30 min vs 60 min: 100C Boil, 100C LiBr, 60C Oven

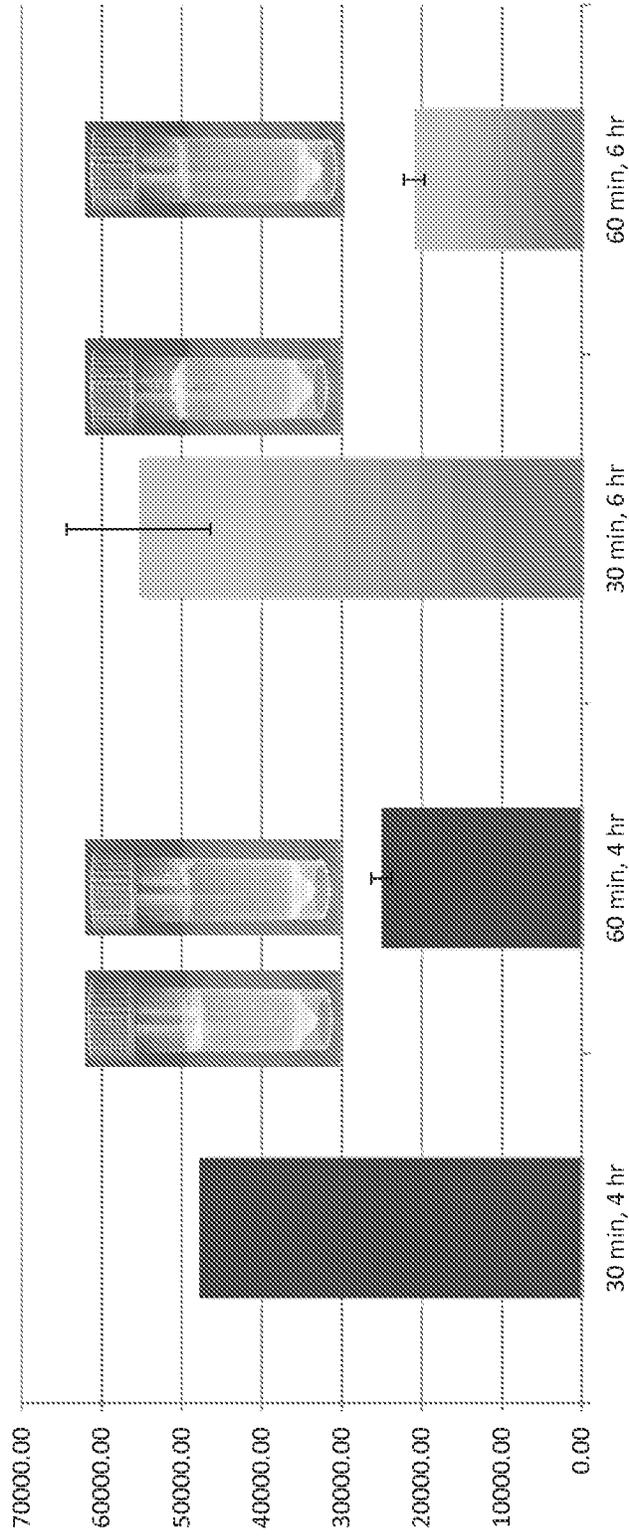


Fig. 69

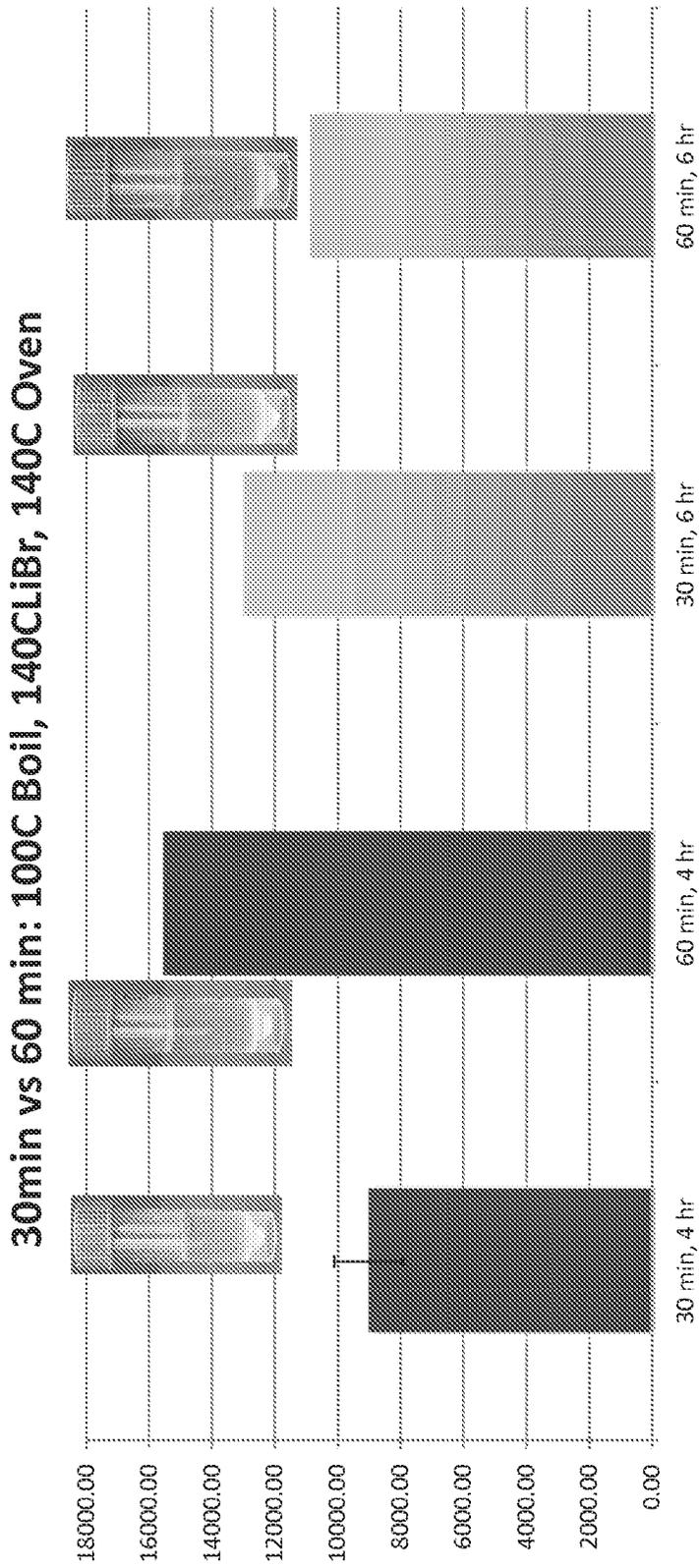


Fig. 70

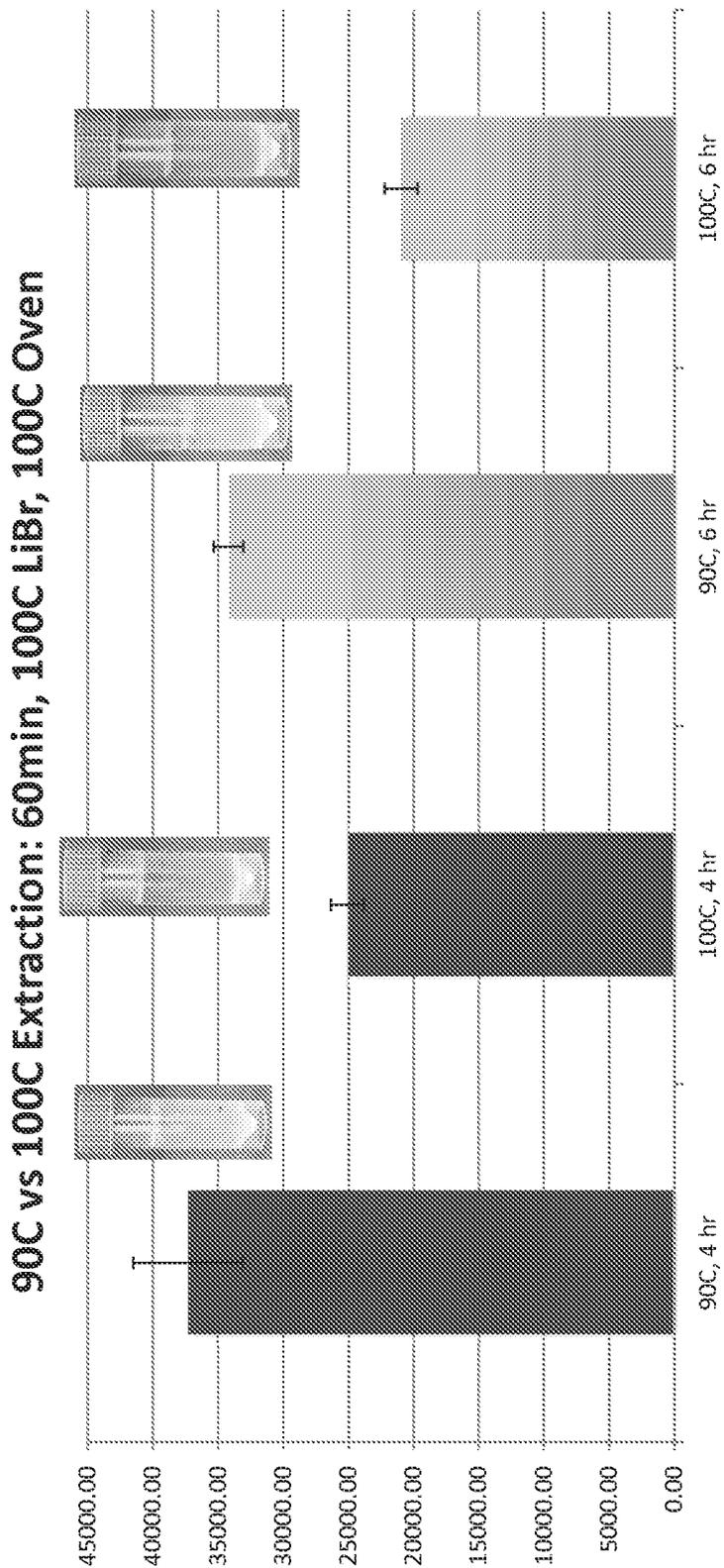


Fig. 71

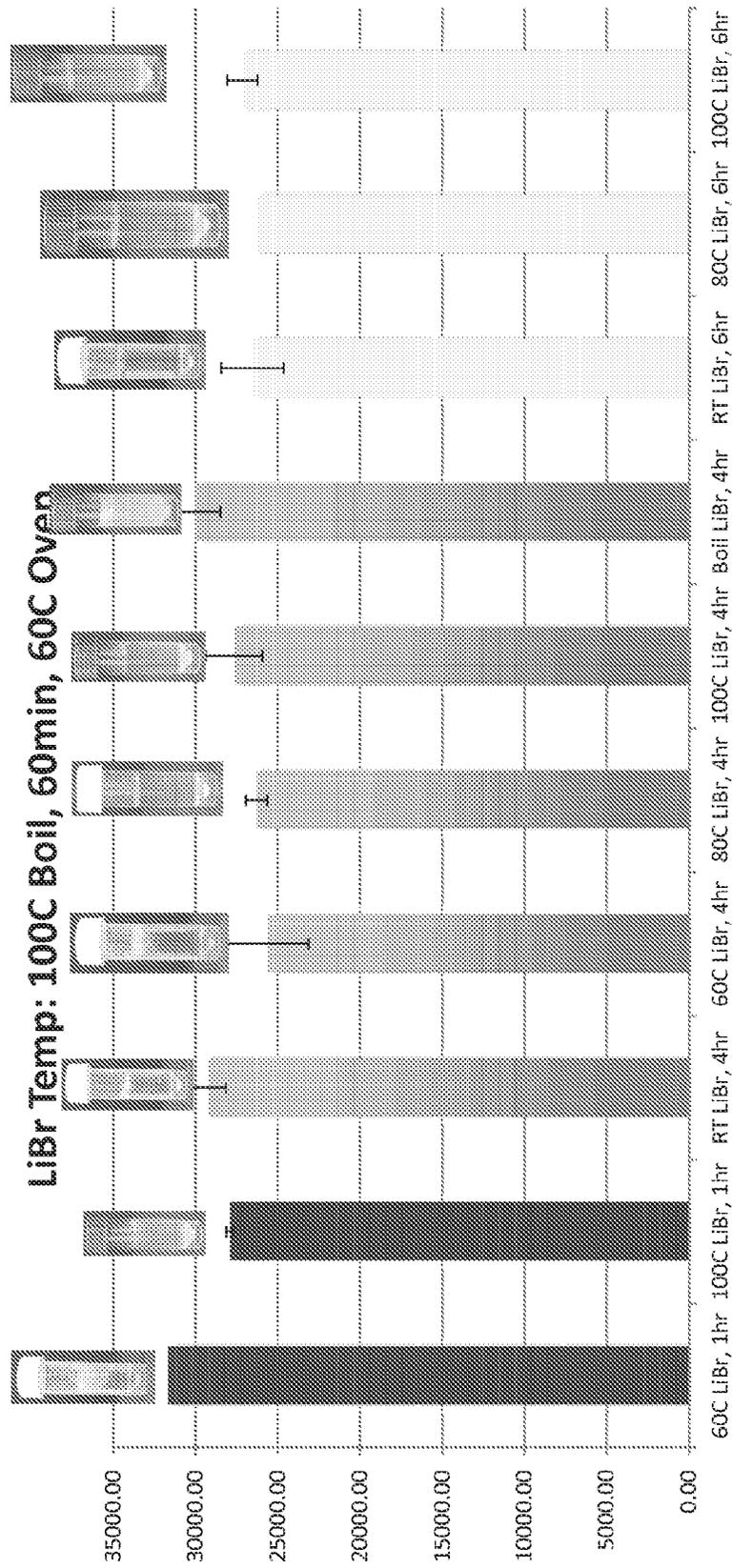


Fig. 72

LiBr Temp: 100C Boil, 30min, 60C Oven

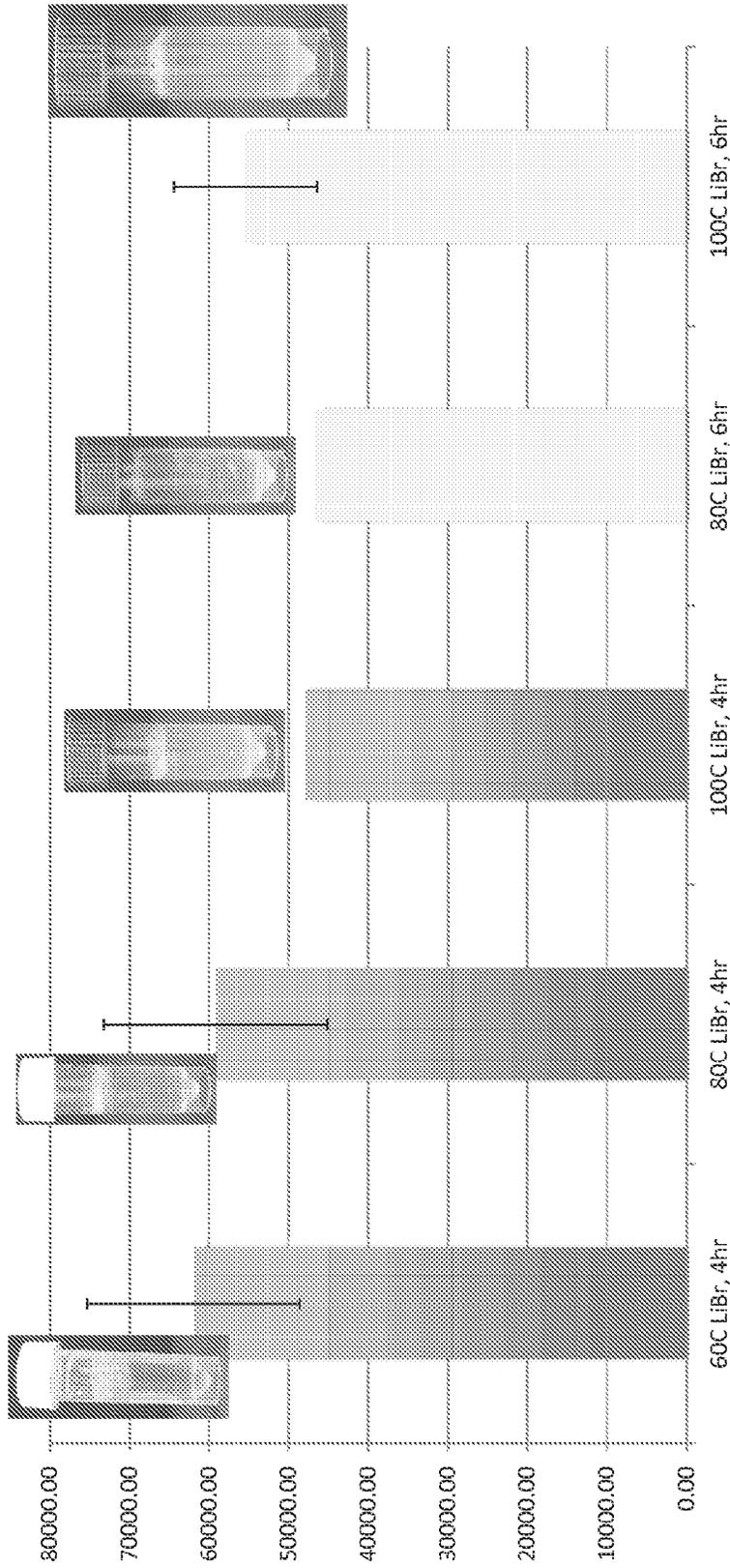


Fig. 73

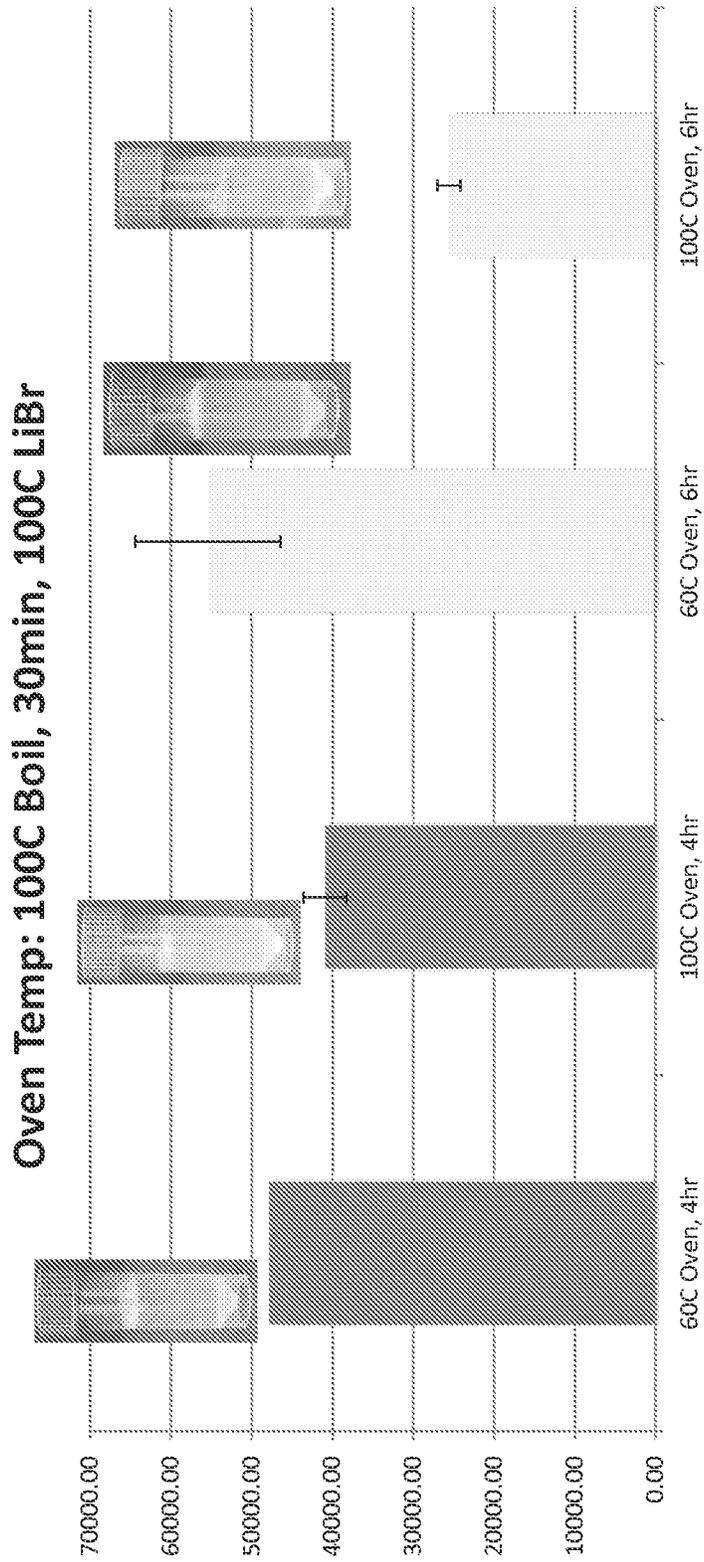


Fig. 74

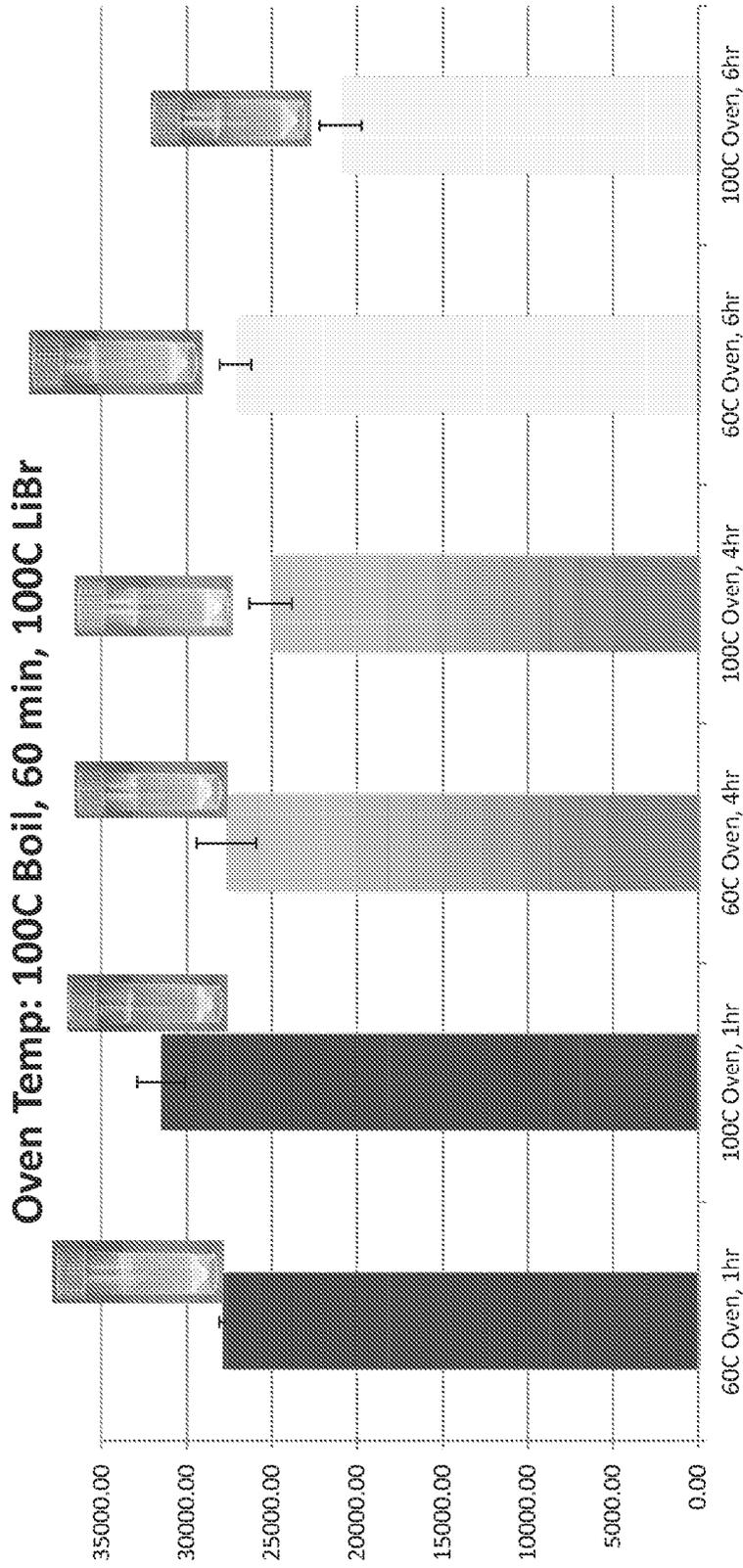


Fig. 75

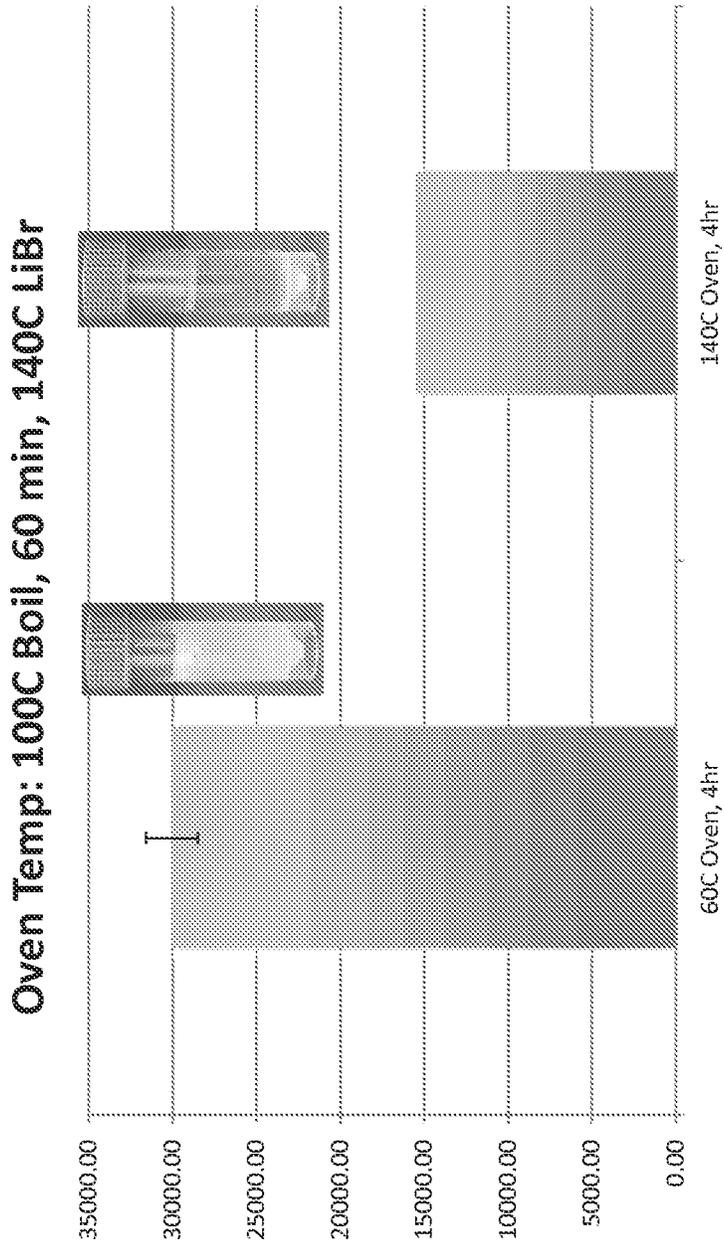


Fig. 76

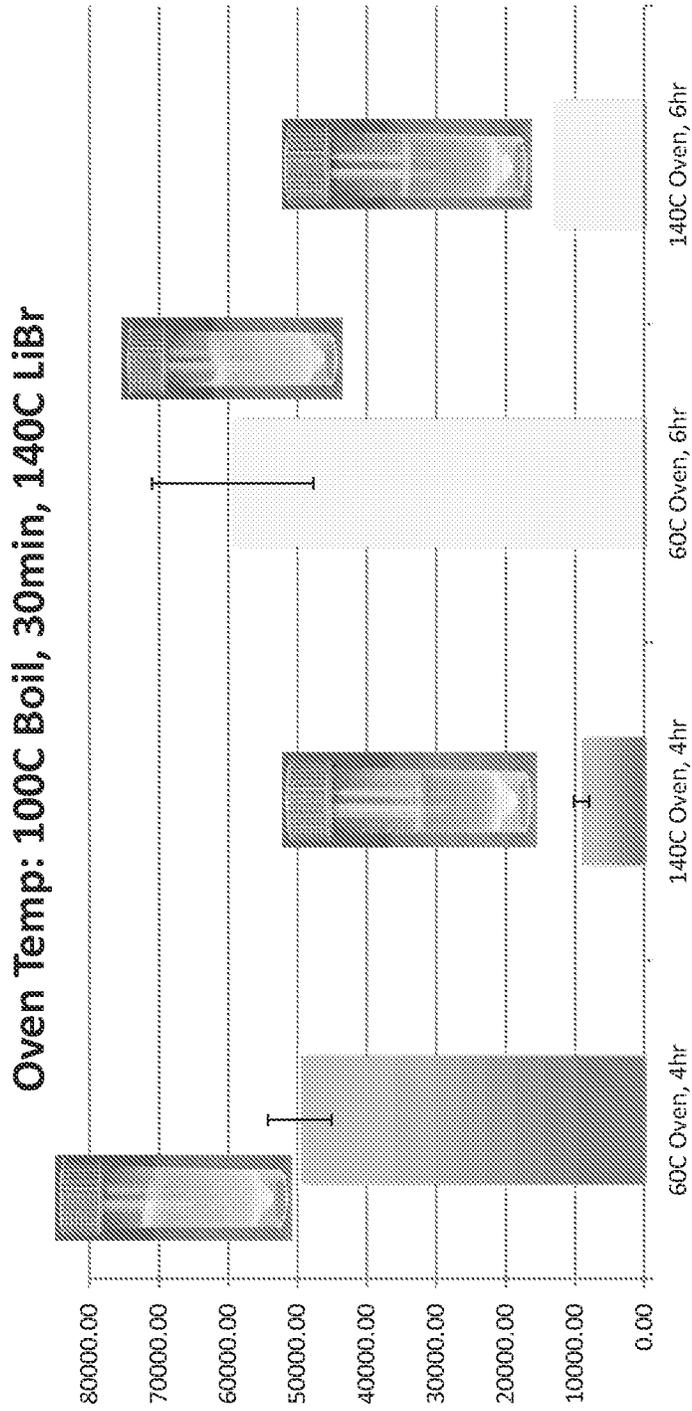


Fig. 77

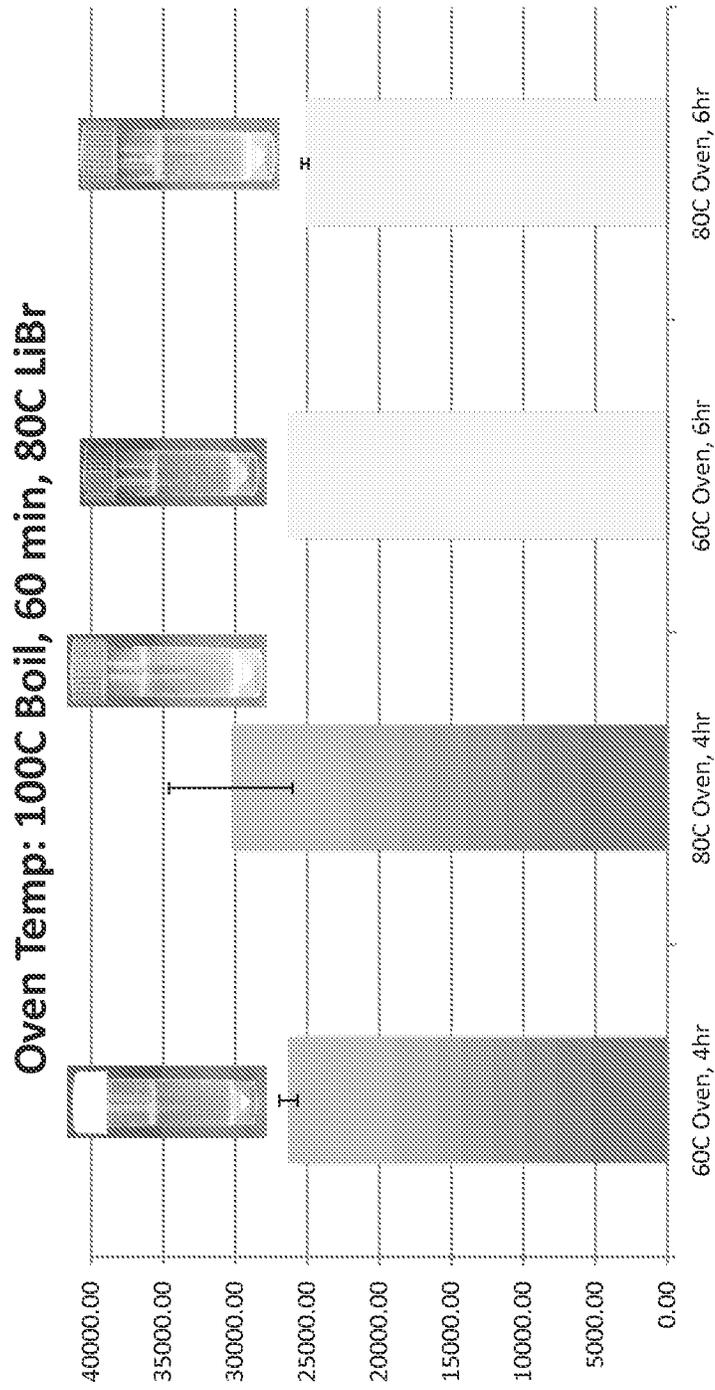


Fig. 78

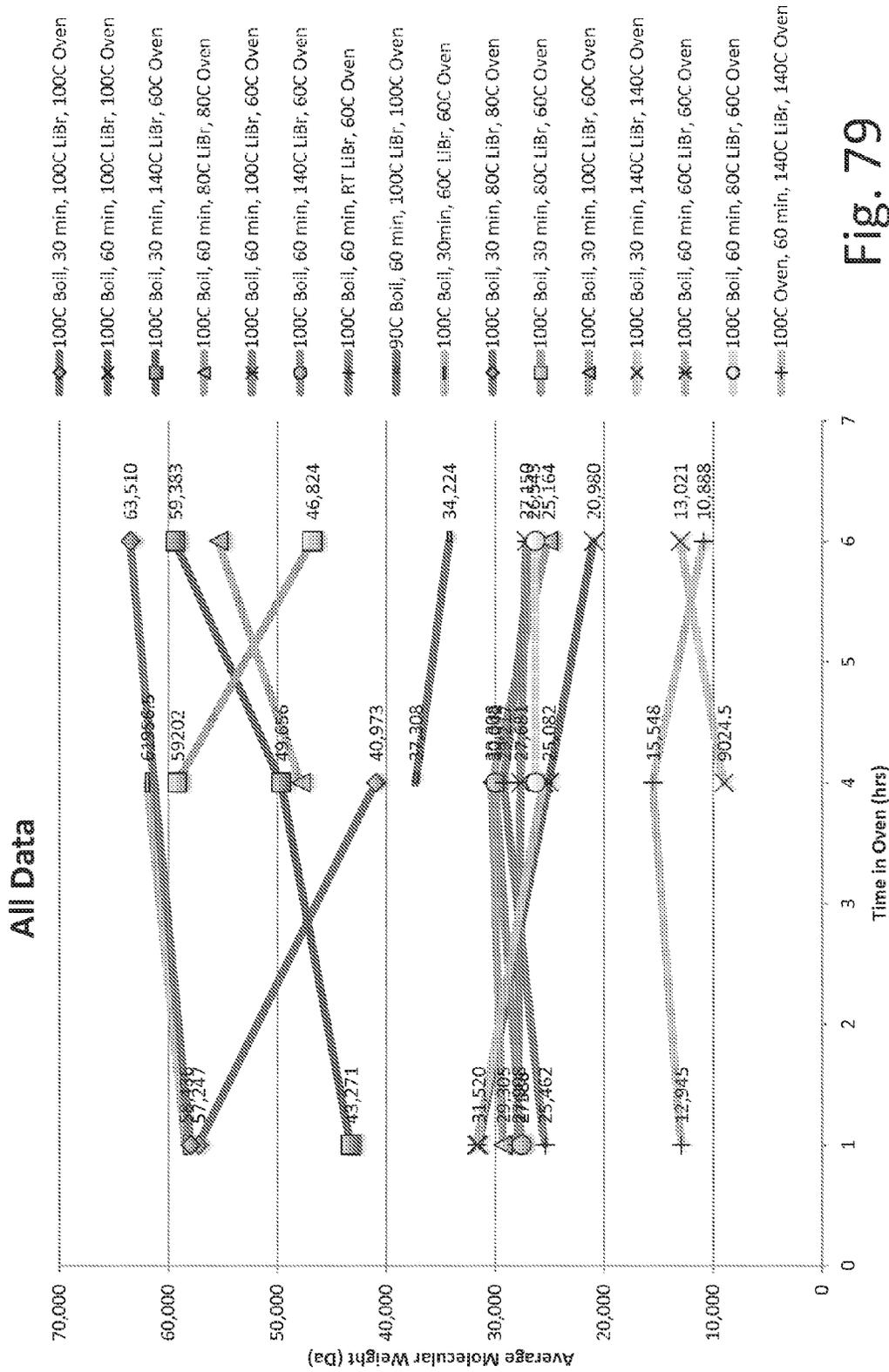


Fig. 79

Oven Temp=LiBr Temp Data: Round 2

Molecular Weight Data: Oven Temp=LiBr Temp

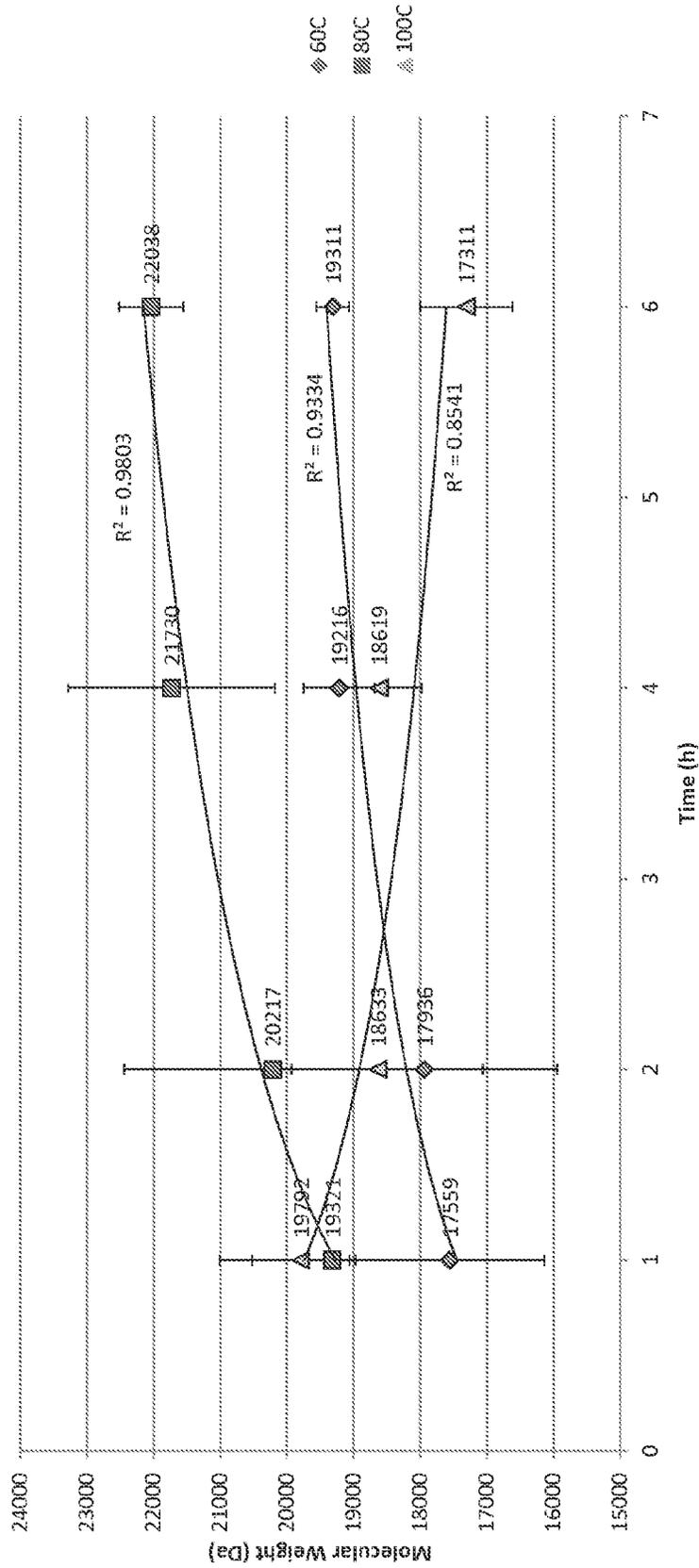


Fig. 80

Vitamin C is Active in PureProc™ Gel

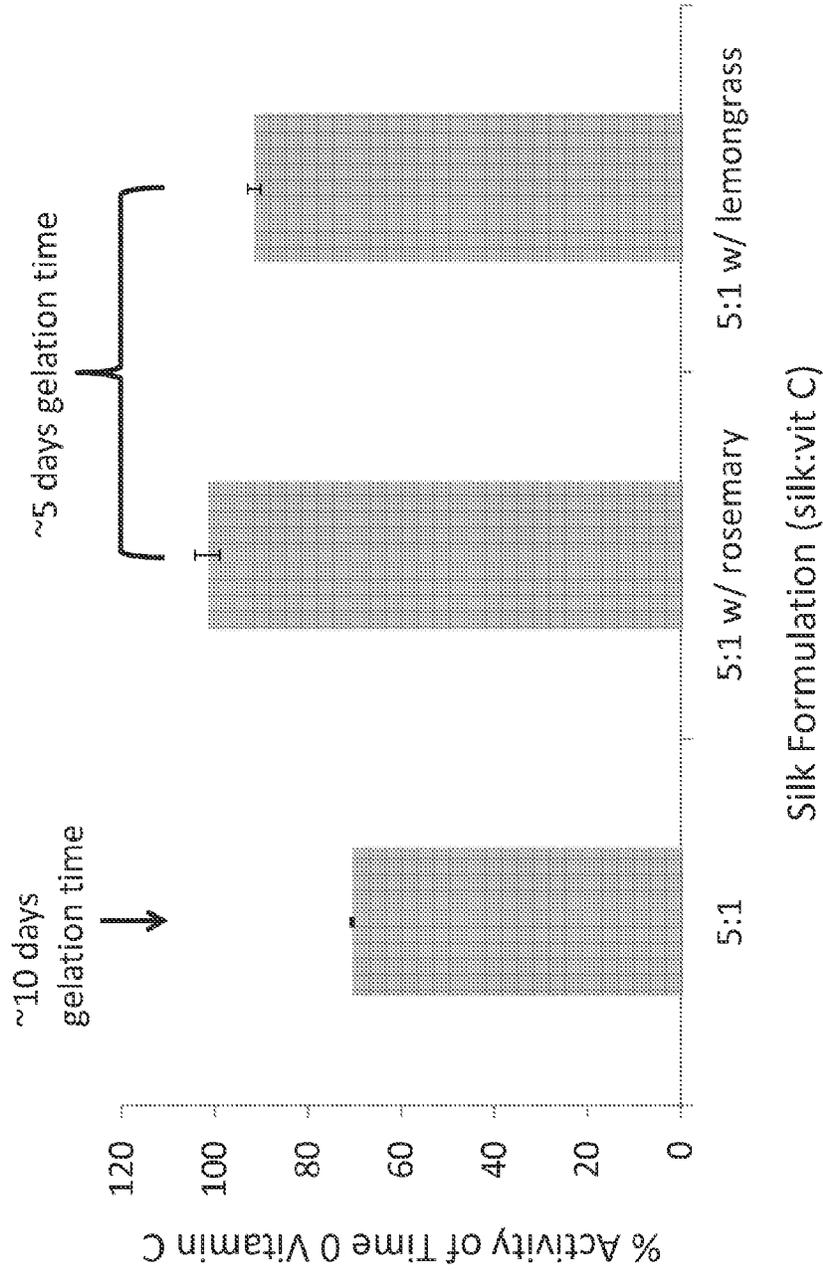


Fig. 81



Figs. 82A-82C

Laser Cutting for Efficiency and Shapes

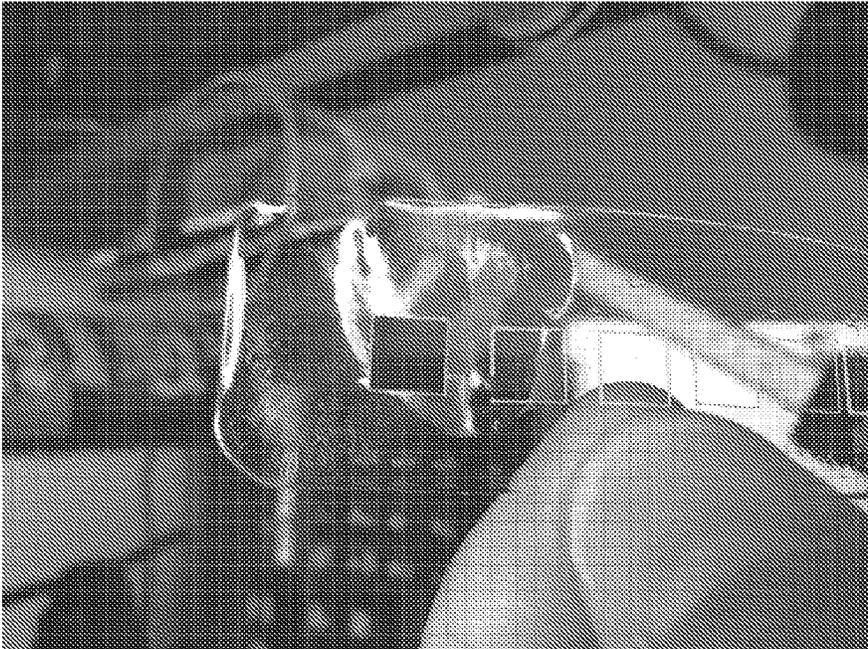


Fig. 83A

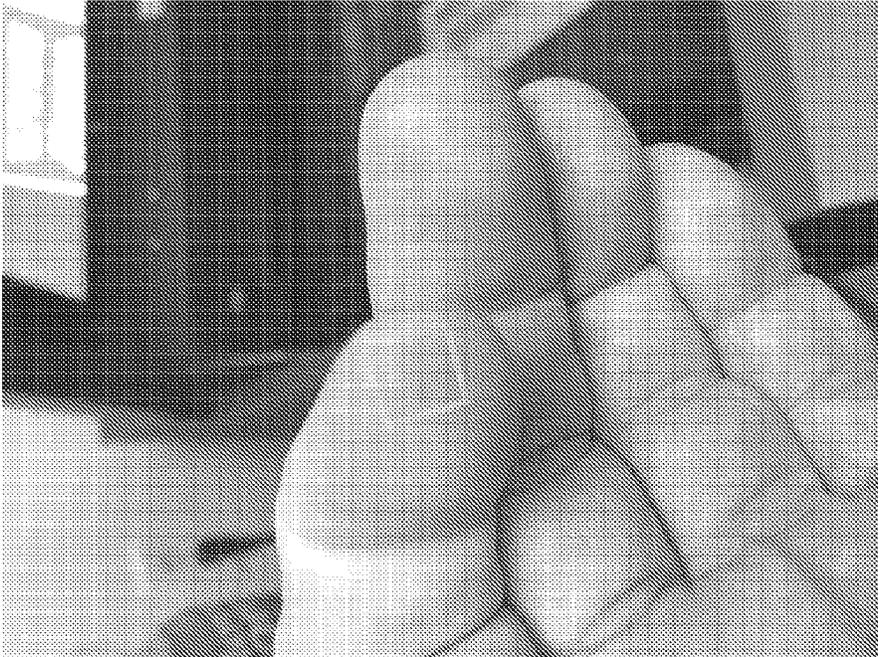


Fig. 83B

Daily Doses of Vitamin C in Cosmetic Products

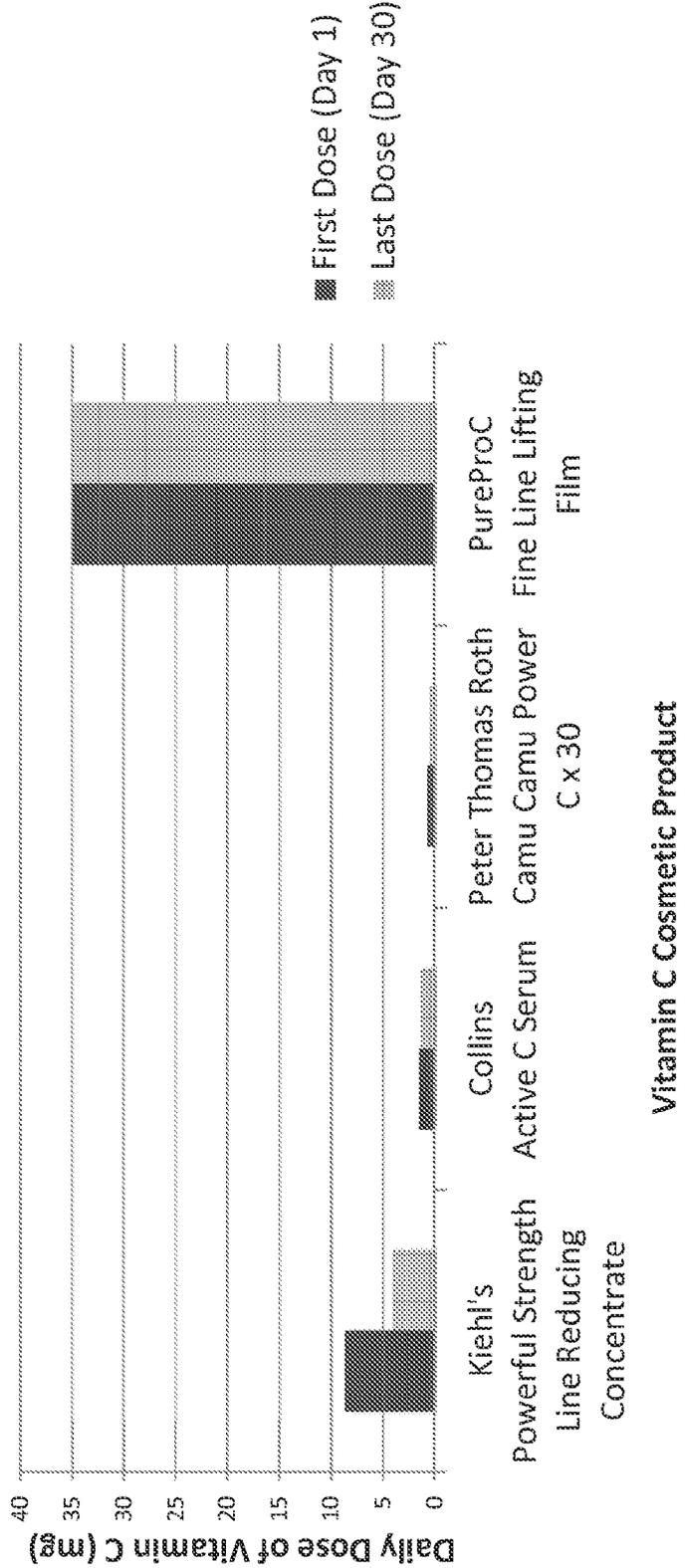


Fig. 84

Ease of Use of PureProc™

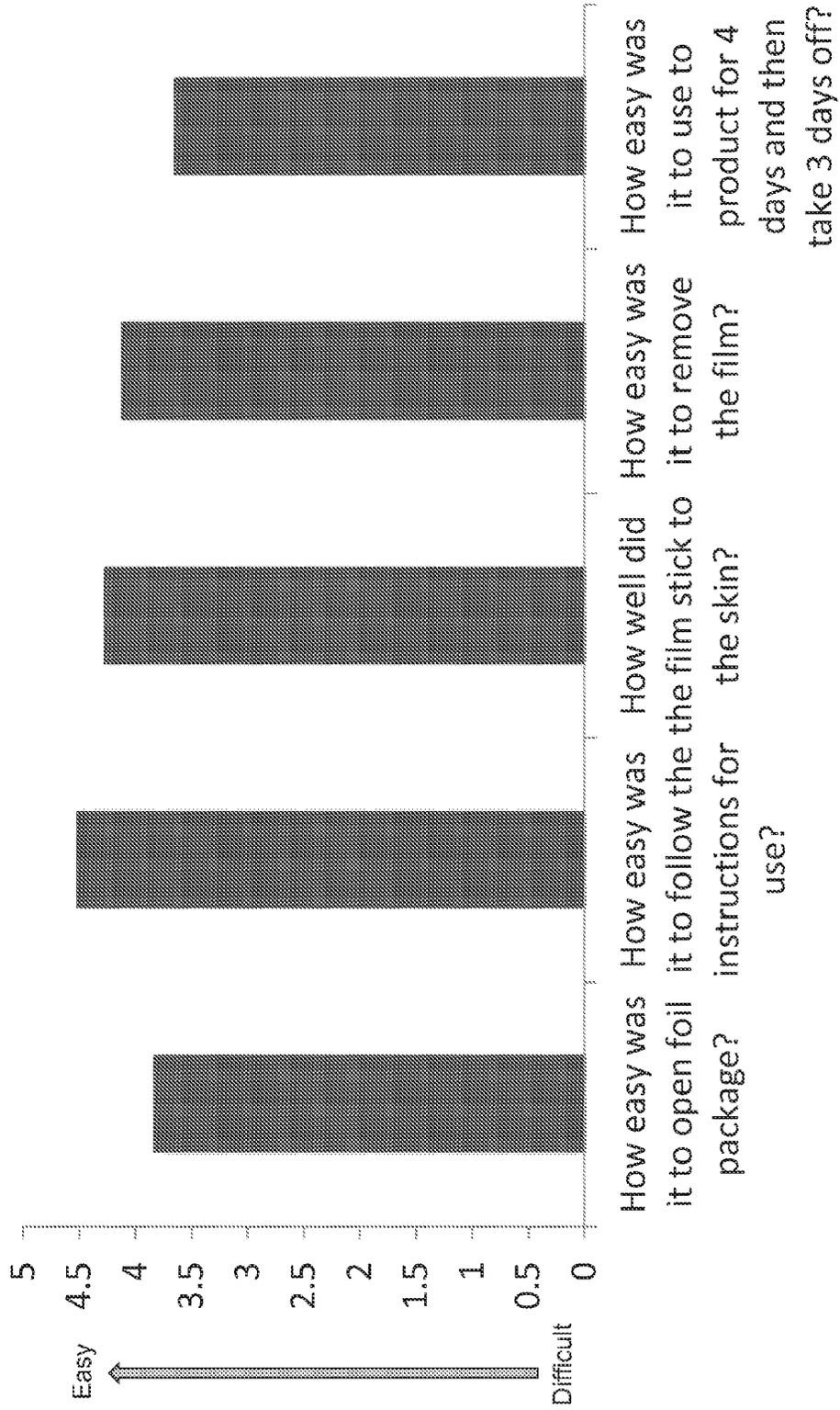


Fig. 85

- Visible benefits from vitamin C use on the skin are most prevalent after 3-6 months continued use
 - The cells on the skin’s surface are replaced by those deep in the dermis approximately once every 28 days
 - Clinical literature has shown vitamin C benefits to be additive with each additional month used as the skin is continually exposed to vitamin C and the cells repeatedly replaced, allowing new collagen to develop and gradually fill fine lines
- Some users saw the initial benefits of their skin feeling better with one month use – longer use will further increase seeing benefits
- User comments:

After 1 Month Use:	Agree	Not Sure	Disagree
My skin feels better	63%	21%	16%
My skin feels firmer	53%	34%	13%
My skin looks brighter	25%	53%	22%
My skin looks more even	25%	47%	28%

Fig. 86

Where did you apply the gel? Choose all that apply.

Answered: 42 Skip to: 2

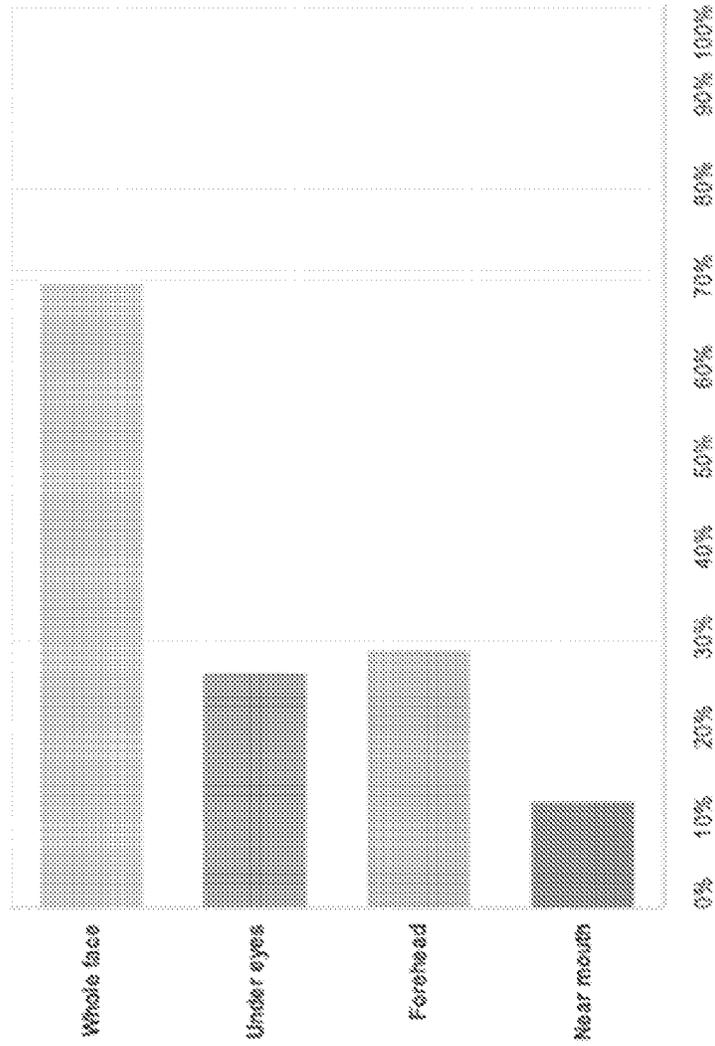


Fig. 87

Thinking only about the lemongrass gel indicate whether you agree with the following statements about your skin after using it.

Answered: 44 Skipped: 0

	Agree	Disagree	Not Sure	Total
My skin looks brighter.	25.00% 11	13.64% 6	61.36% 27	44
My skin tone is better.	34.09% 15	15.91% 7	50.00% 22	44
My skin feels smoother.	56.82% 25	13.64% 6	29.55% 13	44
My skin feels softer.	52.27% 23	9.09% 4	38.64% 17	44
My skin feels better.	50.00% 22	13.64% 6	36.36% 16	44
My skin has improved texture.	43.18% 19	15.91% 7	40.91% 18	44

Fig. 88

Vitamin C Type	% silk in solution	Solution volume per gel (mL)	Mass of Vitamin C per gel (mg)	% Vitamin C	Other Additive Name	Other Additive Quantity	Notes
Sodium Ascorbyl Phosphate (Aromatic)	2	15	100 mg	0.67%	Lemongrass oil	20 uL	No gelation occurred
Sodium Ascorbyl Phosphate (DSM)	2	15	100 mg	0.67%	Lemongrass oil	20 uL	Gelation at ~28days, normal gel appearance
Ascorbyl Tetrapalmitate	2	15	100 mg	0.67%	Lemongrass oil	20 uL	Ascorbyl Tetrapalmitate is a viscous liquid that did not dissolve, solutions were discarded
Ascorbic Acid-2-Glucoside	2	15	100 mg	0.67%	Lemongrass oil	20 uL	Gelation at 3 days, normal gel appearance
l-ascorbic acid and sodium ascorbyl phosphate(DSM)	2	5	25 mg l-ascorbic acid, 25 mg sodium ascorbyl phosphate	1%	Lemongrass oil	6.67 uL	Gelation in 6 days

Fig. 89A

Vitamin C Type	% silk in solution	Solution volume per gel (mL)	Mass of Vitamin C per gel (mg)	% Vitamin C	Other Additive Name	Other Additive Quantity	Notes
l-ascorbic acid and ascorbic acid-2-glucoside	2	5	500 mg l-ascorbic acid, 500 mg ascorbic acid-2-glucoside	20%	Lemongrass oil	6.67 uL	No gelation occurred
l-ascorbic acid and magnesium ascorbyl phosphate	2	5	25 mg l-ascorbic acid, 25 mg magnesium ascorbyl phosphate	1%	Lemongrass oil	6.67 uL	Gelation in 8 days
ascorbic acid-2-glucoside and sodium ascorbyl phosphate	2	5	25 mg ascorbic acid-2-glucoside, 25 mg sodium ascorbyl phosphate	1%	Lemongrass oil	6.67 uL	Gelation in 13 days
ascorbic acid-2-glucoside and magnesium ascorbyl phosphate	2	5	25 mg ascorbic acid-2-glucoside, 25 mg magnesium ascorbyl phosphate	1%	Lemongrass oil	6.67 uL	Gelation in 8 days
l-ascorbic acid and ascorbic acid-2-glucoside	2	5	25 mg l-ascorbic acid, 25 mg ascorbic acid-2-glucoside	1%	Lemongrass oil	6.67 uL	Gelation in 3 days

Fig. 89B

Films:	Vitamin C Type	% Silk Solution	Solution per mold	Mold Area	Vitamin C %	Result	Solubility
1	Sodium Ascorbyl Phosphate (DSM)	2.2	1.56 mL	5.06 cm ²	40	white/opaque, plastic feel, textured (bumpy) top surface	soluble with insoluble borde, some small insoluble pieces
2	Magnesium Ascorbyl Phosphate	2.2	1.56 mL	5.06 cm ²	40	clear/cloudy, plastic feel, textured (rippled) top surface	soluble with insoluble border
3	Ascorbic Acid-2-Glucoside	2.2	1.56 mL	5.06 cm ²	40	clear, less pliable than control, subtle texture on top surface	soluble with insoluble border, some small insoluble pieces
4	L-ascorbic Acid (Control)	2.2	1.56 mL	5.06 cm ²	40	Clear, pliable, no texture	soluble with insoluble border

Fig. 90

% silk in solution	% Vitamin C (l-ascorbic acid) in film	% Caffeine in film	Result
2.4	20	20	dried 19.5 hrs at 24-26C, white crystals on edges, brittle, curled, insoluble in water when applied to skin
2.4	25	15	half dried 18 hours at 24-26C: clear, flexible, pliable, insoluble. Half dried 22 hours at 24-26C: clear, brittle, insoluble
2.4	25	5	dried 51 hours at 24-29C due to high humidity in lab, insoluble films
2.4	25	10	dried 51 hours at 24-29C due to high humidity in lab, insoluble films

Fig. 91A

% silk in solution	% Vitamin C (l-ascorbic acid) in film	% Caffeine in film	Result
2.4	25	0.5	unknown drying time, soluble films
2.4	25	0.5	dried 46 hours at 24-30C, soluble films
2.4	25	1	dried 46 hours at 24-30C, soluble films
2.4	25	2.5	dried 46 hours at 24-30C, soluble films

Fig. 91B

% silk in solution	Gel Volume	Mass Vitamin C (l-ascorbic acid) in gel	Mass Caffeine in gel	Result
2	15 mL	100 mg	50 mg	Gelled in 4 days with exact appearance of standard vitamin C gels

Fig. 92

Sample	volume of solution (mL)	% Silk	Type of Vitamin C	Additive 1 name/quantity	Additive 2 name/quantity	Mass of vitamin C	Days to gel
1	5	2	l-ascorbic acid	Verstatil/75 uL	Dermofeel PA-3/5 uL	33	7
2	5	2	l-ascorbic acid	Verstatil/75 uL	Dermofeel PA-3/5 uL	33	7
3	5	2	l-ascorbic acid	none	none	33	2
4	5	2	ascorbic acid-2-glucoside	none	none	33	5

Fig. 93

Volume of Final Solution	% Silk (Final Solution)	TFF Batch, % Silk	Volume of TFF Batch	Volume of RO/DI water	% HA	Mass HA (mg)	Additive	Additive %	Additive mass (g)	Vitamin C Type	Mass of vitamin C (mg)
5	1	TFF-10-0055, 3.98%	1.25	3.75	1	0.05	Zinc Oxide	10	0.5	Sodium Ascorbyl Phosphate	33
Results Zinc Oxide(ZnO) is insoluble but can be dispersed with viscous HA solution. ZnO was mixed with water before HA and became clumpy. Large white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	1	0.05	Titanium Dioxide	10	0.5	Sodium Ascorbyl Phosphate	33
Results Titanium Dioxide (TiO2) is insoluble but can be dispersed with viscous HA solution. TiO2 was mixed with water before HA and became clumpy. Large white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	1	0.05	Zinc Oxide	5	0.25	Sodium Ascorbyl Phosphate	33
Results ZnO was evenly dispersed after mixing. Solution was low viscosity and ZnO settled to the bottom after a couple days. Minimal white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	1	0.05	Titanium Dioxide	5	0.25	Sodium Ascorbyl Phosphate	33
Results TiO2 was evenly dispersed after mixing. Solution was low viscosity and TiO2 settled to the bottom after a couple days. Minimal white residue on skin when applied.											

Fig. 94A

Volume of Final Solution	% Silk (Final Solution)	TFF Batch, % Silk	Volume of TFF Batch	Volume of RO/DI water	% HA	Mass HA (mg)	Additive	Additive %	Additive mass (g)	Vitamin C Type	Mass of vitamin C (mg)
5	1	TFF-10-0055, 3.98%	1.25	3.75	2.5	0.125	Zinc Oxide	5	0.25	Sodium Ascorbyl Phosphate	33
Results ZnO was evenly dispersed after mixing. Solution was viscosity of syrup and ZnO remained dispersed. Best feel and consistency. Minimal white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	2.5	0.125	Titanium Dioxide	5	0.25	Sodium Ascorbyl Phosphate	33
Results TiO2 was evenly dispersed after mixing. Solution was viscosity of syrup and TiO2 remained dispersed. Minimal white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	5	0.25	Zinc Oxide	5	0.25	Sodium Ascorbyl Phosphate	33
Results ZnO was evenly dispersed after mixing. Solution was of high viscosity and ZnO remained dispersed. Best feel and consistency. Small white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	5	0.25	Titanium Dioxide	5	0.25	Sodium Ascorbyl Phosphate	33
Results TiO2 was evenly dispersed after mixing. Solution was of high viscosity and TiO2 remained dispersed. Small white residue on skin when applied.											
5	1	TFF-10-0055, 3.98%	1.25	3.75	5	0.25	Zinc Oxide	2.5	0.125	Sodium Ascorbyl Phosphate	33
Results ZnO was evenly dispersed after mixing. Solution was of high viscosity and ZnO remained dispersed. Small white residue on skin when applied.											

Fig. 94B

Volume of Final Solution	% Silk (Final Solution)	TFF Batch, % Silk	Volume of TFF Batch	Volume of RO/DI water	% HA	Mass HA (mg)	Additive	Additive %	Additive mass (g)	Vitamin C Type	Mass of vitamin C (mg)
100	1	TFF-10-0057, 3.8%	26.3	73.7	2.5	2.5	Zinc Oxide and Titanium Dioxide	ZnO (3.75%), TiO2 (1.25%)	ZnO (3.75g), TiO2 (1.25g)	Sodium Ascorbyl Phosphate	666
ZnO and TiO2 was evenly dispersed after mixing. Solution was viscosity of syrup. ZnO and TiO2 remained dispersed. Minimal white residue on skin when applied. Mixed with electric mixer.											
100	1	TFF-10-0057, 3.8%	26.3	73.7	2.5	2.5	Zinc Oxide and Titanium Dioxide	ZnO (5.625%), TiO2 (1.875%)	ZnO (5.625g), TiO2 (1.875g)	Sodium Ascorbyl Phosphate	666
ZnO and TiO2 was evenly dispersed after mixing. Solution was viscosity of syrup. ZnO and TiO2 remained dispersed. Minimal white residue on skin when applied. Mixed with electric mixer.											
110	1	TFF-10-0055, 3.83%	29	81	2.5	2.75	Zinc Oxide and Titanium Dioxide	ZnO (12%), TiO2 (3%)	ZnO (13.2g), TiO2 (3.3g)	Sodium Ascorbyl Phosphate	22000
ZnO and TiO2 was evenly dispersed after mixing. Solution was viscosity of glue. ZnO and TiO2 remained dispersed. Minimal white residue on skin when applied. Mixed with electric mixer.											
110	1	TFF-10-0055, 3.83%	29	81	2.5	2.75	Zinc Oxide and Titanium Dioxide	ZnO (15%), TiO2 (5%)	ZnO (16.5g), TiO2 (5.5g)	Sodium Ascorbyl Phosphate	22000
ZnO and TiO2 was evenly dispersed after mixing. Solution was viscosity of glue. ZnO and TiO2 remained dispersed with some visible particles. Minimal white residue on skin when applied. Mixed with electric mixer.											

Fig. 94C

Vit C Type	Volume (ml)	Vit C %	Vit C mass (g)	% silk	lactic acid	lactic acid volume (uL)	Days to gel
l-ascobic acid	5	5	0.25	2	no	N/A	10
l-ascobic acid	5	5	0.25	3	no	N/A	7
l-ascobic acid	5	5	0.25	3.8	no	N/A	5
l-ascobic acid	5	10	0.5	2	no	N/A	Did not gel at 12 days
l-ascobic acid	5	10	0.5	3	no	N/A	Did not gel at 12 days
l-ascobic acid	5	10	0.5	3.8	no	N/A	Did not gel at 12 days
l-ascobic acid	5	15	0.75	2	no	N/A	Did not gel at 12 days
l-ascobic acid	5	15	0.75	3	no	N/A	Did not gel at 12 days
l-ascobic acid	5	15	0.75	3.8	no	N/A	Did not gel at 12 days
l-ascobic acid	5	20	1	2	no	N/A	Did not gel at 12 days
l-ascobic acid	5	20	1	3	no	N/A	Did not gel at 12 days
l-ascobic acid	5	20	1	3.8	no	N/A	Did not gel at 12 days

Fig. 95A

Vit C Type	Volume (ml)	Vit C %	Vit C mass (g)	% silk	lactic acid	lactic acid volume (uL)	Days to gel
ascorbic acid 2 glucoside	5	5		2	no	N/A	4
ascorbic acid 2 glucoside	5	5		3	no	N/A	4
ascorbic acid 2 glucoside	5	5		3.8	no	N/A	3
ascorbic acid 2 glucoside	5	10		2	no	N/A	7
ascorbic acid 2 glucoside	5	10		3	no	N/A	7
ascorbic acid 2 glucoside	5	10		3.8	no	N/A	5
ascorbic acid 2 glucoside	5	15		2	no	N/A	Did not gel at 12 days
ascorbic acid 2 glucoside	5	15		3	no	N/A	Did not gel at 12 days
ascorbic acid 2 glucoside	5	15		3.8	no	N/A	12
ascorbic acid 2 glucoside	5	20		2	no	N/A	Did not gel at 12 days
ascorbic acid 2 glucoside	5	20		3	no	N/A	Did not gel at 12 days
ascorbic acid 2 glucoside	5	20		3.8	no	N/A	Did not gel at 12 days

Fig. 95B

Vit C Type	Volume (ml)	Vit C %	Vit C mass (g)	% silk	lactic acid	lactic acid volume (uL)	Days to gel
L-ascobic acid	5	20		3	yes	5	Did not gel at 12 days
L-ascobic acid	5	10		3	yes	5	Did not gel at 12 days
L-ascobic acid	5	20		5.5	no	N/A	Did not gel at 12 days

Fig. 95C

Test Substance	Microorganism Type	Detection Media	CFU/mL or gram	In Use for (days, if applicable)
Water Sample #1 (from 55 gallon tank)	Aerobic Bacteria	Tryptic Soy agar	1.00E+01	N/A
	Yeast and Mold	Potato Dextrose Agar	<10	
Water Sample #2 (from 5 gallon carboy)	Aerobic Bacteria	Tryptic Soy agar	5.60E+02	N/A
	Yeast and Mold	Potato Dextrose Agar	1.25E+02	
Water Sample #3 (tap water)	Aerobic Bacteria	Tryptic Soy agar	<10	N/A
	Yeast and Mold	Potato Dextrose Agar	<10	
Pure ProC Silk Smoothing Gel with Lemon Grass	Aerobic Bacteria	Tryptic Soy agar	1.00E+01	0
	Yeast and Mold	Potato Dextrose Agar	<10	
Pure ProC Silk Smoothing Gel with Rosemary	Aerobic Bacteria	Tryptic Soy agar	<10	0
	Yeast and Mold	Potato Dextrose Agar	<10	
Water Sample #1 (5 gallon)	Aerobic Bacteria	Tryptic Soy agar	1.00E+01	N/A
	Yeast and Mold	Potato Dextrose Agar	<10	
Water Sample #2 (55 gallon tank)	Aerobic Bacteria	Tryptic Soy agar	<10	N/A
	Yeast and Mold	Potato Dextrose Agar	<10	
Water Sample #1 (carboy)	Aerobic Bacteria	Tryptic Soy agar	2.50E+01	N/A
	Yeast and Mold	Potato Dextrose Agar	<10	
Water Sample #2 (gallon tank)	Aerobic Bacteria	Tryptic Soy agar	<10	N/A
	Yeast and Mold	Potato Dextrose Agar	<10	
Pure ProC Silk Smoothing Gel with Rosemary	Aerobic Bacteria	Tryptic Soy agar	<10	26
	Yeast and Mold	Potato Dextrose Agar	<10	
Pure ProC Silk Smoothing Gel with Lemongrass	Aerobic Bacteria	Tryptic Soy agar	<10	25
	Yeast and Mold	Potato Dextrose Agar	<10	

Fig. 96

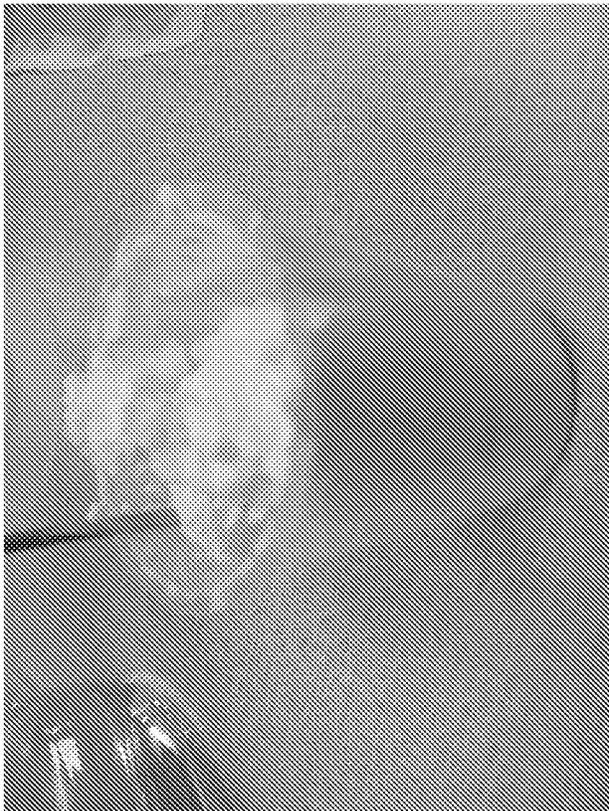


Fig. 97



Fig. 98



Fig. 99

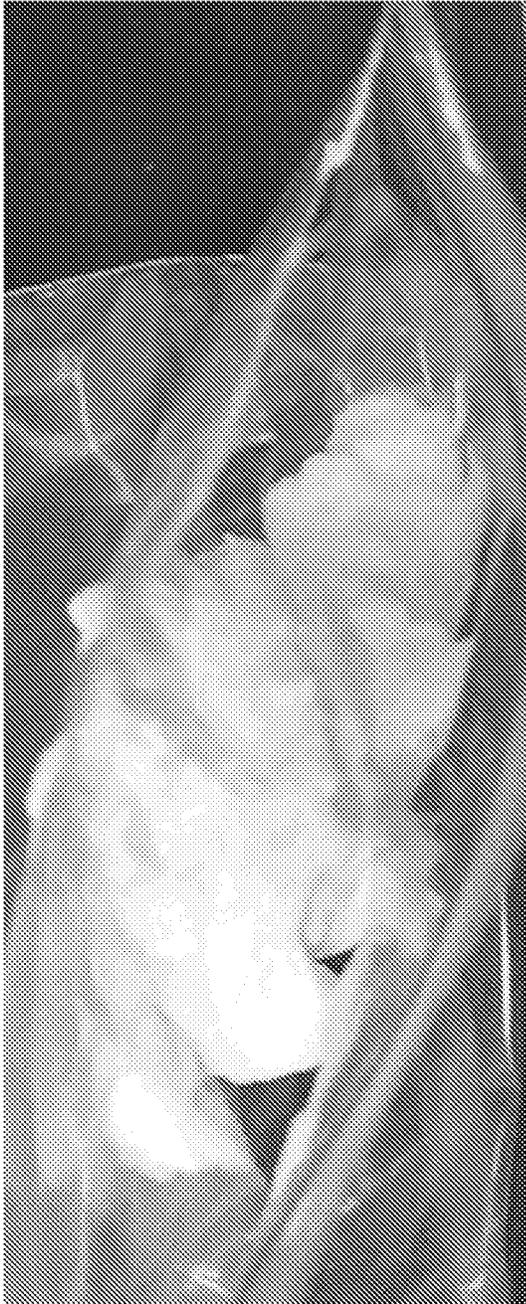


Fig. 100

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STABLE SILK PROTEIN FRAGMENT COMPOSITIONS

RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/503,021 filed Sep. 30, 2014, which application claims priority to and claims the benefit of U.S. Provisional Application No. 61/884,820, filed Sep. 30, 2013, U.S. Provisional Application No. 62/000,928, filed May 20, 2014, and U.S. Provisional Application No. 62/036,450, filed Aug. 12, 2014. The contents of each of these applications are incorporated herein by reference in their entireties.

BACKGROUND

Silk is a natural polymer produced by a variety of insects and spiders. Silk comprises a filament core protein, silk fibroin, and a glue-like coating consisting of a non-filamentous protein, sericin. Silk has been historically studied for use in the medical field. Silk has been well described in its natural fibrous form and is being studied further for potentially useful secondary forms such as silk gels, sponges, serums, films, powders and composites. Many of these secondary forms can only be created after processing the silk fibers into an aqueous silk solution.

Silk solutions have been generated using a variety of methods with the final solutions having a range of characteristics and varying levels of purity. Silk solutions have not only been used in medical applications, but have also expanded to other areas such as cosmetics and electronics.

SUMMARY

Silk protein fragment compositions and articles manufactured therefrom are disclosed herein. Silk protein fragment compositions are further processed to remove water to varying levels resulting in a range of articles from lyophilized powder to aqueous gels. In an embodiment, an article of the present disclosure is a silk film. In an embodiment, a silk film of the present disclosure can be used to address fine lines and wrinkles of the skin, for example fine lines and wrinkles around the mouth and nose. In an embodiment, a silk film of the present disclosure can be used to address dark spots on the skin. In an embodiment, a silk film of the present disclosure is used for reducing puffy eyes. In an embodiment, an article of the present disclosure is a silk gel. In an embodiment, a silk gel of the present disclosure can be used as a firming eye gel. In an embodiment, a silk gel of the present disclosure can replenish moisture and increase cell renewal while restoring radiance. In an embodiment, a silk gel of the present disclosure is a soothing gel. In an embodiment, a silk gel of the present disclosure is used for reducing puffy eyes. In an embodiment, a silk gel of the present disclosure is used for reducing dark circles around the eyes. In an embodiment, an article of the present disclosure is a silk serum. In an embodiment, a silk serum of the present disclosure can be used as a hydrating serum to restore hydration to the skin. In an embodiment, a silk serum of the present disclosure can be used to treat redness, acne and hyperpigmentation of the skin. In an embodiment, an article of the present disclosure is a silk chemical peel that damages the skin in a controlled manner. In an embodiment, a silk chemical peel of the present disclosure, when applied to the skin, results in healthy vibrant skin. In an embodiment, a silk chemical peel of the present disclosure, when applied to the skin, results in a reduction in fine lines. In an

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embodiment, a silk chemical peel of the present disclosure, when applied to the skin, results in firming of the skin. In an embodiment, an article of the present disclosure is a silk sunscreen gel.

5 According to aspects illustrated herein, methods for preparing aqueous solutions of pure silk fibroin-based protein fragments are disclosed. In an embodiment, at least one pure silk fibroin-based protein fragment (SPF) mixture solution having a specific average weight average molecular weight (MW) range and polydispersity is created. In an embodiment, at least SPF mixture solution having a MW range between about 6 kDa and 16 kDa and a polydispersity range between about 1.5 and about 3.0 is created. In an embodiment, at least one SPF mixture solution having a MW 10 between about 17 kDa and 38 kDa and a polydispersity range between about 1.5 and about 3.0 is created. In an embodiment, at least one SPF mixture solution having a MW range between about 39 kDa and 80 kDa and a polydispersity range between about 1.5 and about 3.0 is created.

15 According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm 20 of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, 25 the composition further includes less than 10% water. In an embodiment, the composition is in the form of a lyophilized structure, such as a lyophilized powder. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.1 wt % to about 30.0 wt % pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term “stable” refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term “stable” refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, antioxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino gly- 30 cans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more

molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic. In an embodiment, the pure silk fibroin-based protein fragments are bioresorbable or biodegradable following implantation or application.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a lyophilized structure, such as a lyophilized powder. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.1 wt % to about 30.0 wt % pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, antioxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino glycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an

embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic. In an embodiment, the pure silk fibroin-based protein fragments are bioresorbable or biodegradable following implantation or application.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a lyophilized structure, such as a lyophilized powder. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.1 wt % to about 30.0 wt % pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, antioxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino glycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic. In an embodiment, the pure silk

fibroin-based protein fragments are bioresorbable or biodegradable following implantation or application.

According to aspects illustrated herein, there is disclosed a film that includes pure silk fibroin-based protein fragments substantially devoid of sericin and comprising: an average weight average molecular weight ranging from about 17 kDa to about 38 kDa; and a polydispersity of between about 1.5 and about 3.0, wherein the film has a water content ranging from about 2.0 wt. % to about 20.0 wt. %, wherein the film includes between 0 ppm and 500 ppm of inorganic residuals, wherein the film includes between 0 ppm and 500 ppm of organic residuals, and wherein the film is sufficiently flexible to conform to anatomical topographies. In an embodiment, the film includes between about 1.0% and about 50.0% crystalline protein domains and being soluble when submersed in water at room temperature. In an embodiment, the film includes from about 30.0 wt. % to about 99.5 wt. % of pure silk fibroin-based protein fragments. In an embodiment, the film has a pH from about 1.0 to about 7.0. In an embodiment, the film further includes from about 0.5 wt. % to about 2.5 wt. % of caffeine. In an embodiment, the film further includes from about 1.0 wt. % to about 50.0 wt. % of vitamin C or a derivative thereof. In an embodiment, the vitamin C or a derivative thereof remains stable within the film for a period of from about 5 days to about 5 years. In an embodiment, the vitamin C or a derivative thereof is stable within the film so as to result in release of the vitamin C in a biologically active form. In an embodiment, the film further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, antioxidants, proteins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosamino glycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, polyanhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the film further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the film further includes hyaluronic acid or its salt form at a concentration ranging from about 0.5 wt. % to about 10.0 wt. %. In an embodiment, the film further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the film is packaged in a foil based package that is air tight and light proof. In an embodiment, the film is sufficiently designed for topical application. In an embodiment, the topical application is for cosmetic use. In an embodiment, the topical application is for wound dressing. In an embodiment, the film is sufficiently designed for administration within a body. In an embodiment, the pure silk fibroin-based protein fragments are hypoallergenic. In an embodiment, a method of reducing fine lines and wrinkles includes applying a film of the present disclosure daily to human skin for a period of at least one week and observing a reduction in fine lines and wrinkles on the human skin.

According to aspects illustrated herein, there is disclosed a gel that includes pure silk fibroin-based protein fragments substantially devoid of sericin and comprising: an average weight average molecular weight ranging from about 17 kDa to about 38 kDa; and a polydispersity of between about 1.5 and about 3.0; and water from about 20 wt. % to about 99.9 wt. %, wherein the gel includes between 0 ppm and 500 ppm of inorganic residuals, and wherein the gel includes between 0 ppm and 500 ppm of organic residuals. In an embodiment, the gel includes between about 1.0% and about 50.0% crystalline protein domains. In an embodiment, the

gel includes from about 0.1 wt. % to about 6.0 wt. % of pure silk fibroin-based protein fragments. In an embodiment, the gel has a pH from about 1.0 to about 7.0. In an embodiment, the gel further includes from about 0.5 wt. % to about 20.0 wt. % of vitamin C or a derivative thereof. In an embodiment, the vitamin C or a derivative thereof remains stable within the gel for a period of from about 5 days to about 5 years. In an embodiment, the vitamin C or a derivative thereof is stable within the gel so as to result in release of the vitamin C in a biologically active form. In an embodiment, the gel further includes an additive selected from the group consisting of vitamin E, rosemary oil, rose oil, lemon juice, lemon grass oil and caffeine. In an embodiment, the gel is packaged in an airtight container. In an embodiment, the pure silk fibroin-based protein fragments are hypoallergenic. In an embodiment, the gel has less than 10 colony forming units per milliliter. In an embodiment, a method of smoothing and rejuvenating human skin includes applying a gel of the present disclosure daily to human skin for a period of at least one week and observing an improvement in skin texture.

According to aspects illustrated herein, there is disclosed a serum that includes pure silk fibroin-based protein fragments substantially devoid of sericin and comprising: an average weight average molecular weight ranging from about 17 kDa to about 38 kDa; and a polydispersity of between about 1.5 and about 3.0; and hyaluronic acid or its salt form from about 0.5% to about 10.0%, wherein the serum includes between 0 ppm and 500 ppm of inorganic residuals, and wherein the serum includes between 0 ppm and 500 ppm of organic residuals. In an embodiment, the serum includes between about 1.0% and about 50.0% crystalline protein domains. In an embodiment, the serum includes from about 0.1 wt. % to about 6.0 wt. % of pure silk fibroin-based protein fragments. In an embodiment, the serum has a pH from about 1.0 to about 7.0. In an embodiment, the serum further includes an additive selected from the group consisting of vitamin E, rosemary oil, rose oil, lemon juice, lemon grass oil, vanilla, geranium, and green tea. In an embodiment, the serum further includes from about 0.5 wt. % to about 30.0 wt. % of vitamin C or a derivative thereof. In an embodiment, the vitamin C or a derivative thereof remains stable within the serum for a period of from about 5 days to about 5 years. In an embodiment, the vitamin C or a derivative thereof is stable within the serum so as to result in release of the vitamin C in a biologically active form. In an embodiment, the serum is packaged in an airtight container. In an embodiment, the pure silk fibroin-based protein fragments are hypoallergenic. In an embodiment, a method of moisturizing human skin includes applying daily a serum of the present disclosure to human skin for a period of at least one week and observing an improvement in skin hydration.

According to aspects illustrated herein, there is disclosed a skin peel composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, the fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa and a polydispersity of between about 1.5 and about 3.0 in combination with at least one skin exfoliating agent. In an embodiment, the skin peel composition includes at least one skin exfoliating agent selected from the group consisting of glycolic acid and lactic acid. In an embodiment, the skin peel composition includes between about 1.0% and about 50.0% crystalline protein domains. In an embodiment, the skin peel

composition has a pH from about 1.0 to about 6.0. In an embodiment, the pure silk fibroin-based protein fragments are hypoallergenic.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, the method including the steps of: degumming a silk source by adding the silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 60° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in an oven having a temperature of about 140° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of silk protein fragments, the aqueous solution comprising: fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of lyophilizing the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, a cosmetic film is fabricated from the aqueous solution of silk protein fragments. In an embodiment, a cosmetic gel is fabricated from the aqueous solution of silk protein fragments.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, the method including the steps of: adding a

silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, wherein the aqueous solution of silk protein fragments comprises sodium carbonate residuals of between about 10 ppm and about 100 ppm, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of lyophilizing the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, a cosmetic film is fabricated from the aqueous solution of silk protein fragments. In an embodiment, a cosmetic gel is fabricated from the aqueous solution of silk protein fragments.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, the method including the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium

carbonate for a treatment time of about 30 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, sodium carbonate residuals of between about 10 ppm and about 100 ppm, fragments having an average weight average molecular weight ranging from about 40 kDa to about 65 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of lyophilizing the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, a cosmetic film is fabricated from the aqueous solution of silk protein fragments. In an embodiment, a cosmetic gel is fabricated from the aqueous solution of silk protein fragments.

According to aspects illustrated herein, silk films manufactured from SPF mixture solutions of the present disclosure are disclosed. In an embodiment, at least one molecule or therapeutic agent of interest is physically entrapped into a SPF mixture solution of the present disclosure during processing into films. A silk film of the present disclosure can be used to release at least one molecule or therapeutic agent of interest.

According to aspects illustrated herein, a method is disclosed for producing silk films having entrapped molecules or therapeutic agents.

According to aspects illustrated herein, a method is disclosed for producing silk gels having entrapped molecules or therapeutic agents such as those listed in the following paragraph. In an embodiment, at least one molecule or therapeutic agent of interest is physically entrapped into a SPF mixture solution of the present disclosure during processing into aqueous gels. An aqueous silk gel of the present disclosure can be used to release at least one molecule or therapeutic agent of interest.

According to aspects illustrated herein, a SPF mixture solution of the present disclosure is used to fabricate a silk film or aqueous gel that entraps molecules including, but not limited to, Selenium, Ubiquinone derivatives, Thiol-based antioxidants, Saccharide-containing antioxidants, Polyphenols, Botanical extracts, Caffeic acid, Apigenin, Pycnogenol, Resveratrol, Folic acid, Vitamin b12, Vitamin b6, Vitamin b3, Vitamin E, Vitamin C and derivatives thereof, Vitamin D, Vitamin A, Astaxathin, Lutein, Lycopene, Essential fatty acids (omegas 3 and 6), Iron, Zinc, magnesium, Flavonoids (soy, Curcumin, Silymarin, Pycnongeol), Growth factors, aloe, hyaluronic acid, extracellular matrix proteins, cells, nucleic acids, biomarkers, biological reagents, zinc oxide, benzoyl peroxide, retinoids, titanium, caffeine, green tea, allergens in a known dose (for sensitization treatment), essential oils including, but not limited to, lemongrass or rosemary oil, and fragrances. A film of the present disclosure can adhere to the skin when moistened, allowing for easy application and targeted delivery to a treatment area with an ability to be wiped off with water. Molecule loaded films, gels or serums can be used for drug delivery, medical and personal care, including anti-aging, wrinkle and fine line reduction and prevention, crows feet, frown lines and glabella line reduction; acne treatment; UV protection; all types of wound care; topical, intradermal and sub-dermal and implantable medical and pharmaceutical applications; all types and conditions of inflammation, such as eczema or rosacea; creating an even skin tone, pigment reduction, hyperpigmentation treatment, dark spots or age spots resulting from acne, pregnancy, birth control, photodamage; reducing scar and stretch marks, and reducing acne scarring. By stabilizing molecules in a film or gel of the present disclosure, controlled release of the molecule in its active form is achieved. In an embodiment, a film or gel of the present disclosure can deliver its molecule in a time frame relevant to a consumer for daily skin treatment(s). In an embodiment, the pure silk fibroin-based protein composition in an aqueous or organic solution may be used to spin fibers or fabrics for the medical or consumer markets.

BRIEF DESCRIPTION OF THE DRAWINGS

The presently disclosed embodiments will be further explained with reference to the attached drawings. The drawings shown are not necessarily to scale, with emphasis instead generally being placed upon illustrating the principles of the presently disclosed embodiments.

FIG. 1 is a flow chart showing various embodiments for producing pure silk fibroin-based protein fragments (SPFs) of the present disclosure.

FIG. 2 is a flow chart showing various parameters that can be modified during the process of producing SPFs of the present disclosure during the extraction and the dissolution steps.

FIG. 3 is a photograph showing dry extracted silk fibroin.

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FIG. 4 is a photograph showing an embodiment of a SPF in the form of a solution of the present disclosure.

FIGS. 5A-5D are photographs showing dissolved silk in room temperature lithium bromide (LiBr) solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 6A-6D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 7A-7D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 8 hours (sericin extraction temperature and time were varied).

FIGS. 8A-8D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 12 hours (sericin extraction temperature and time were varied).

FIGS. 9A-9D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 24 hours (sericin extraction temperature and time were varied).

FIGS. 10A-10D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 168/192 hours (sericin extraction temperature and time were varied).

FIGS. 11A-11C are photographs showing dissolved silk in room temperature LiBr solutions dissolved in 60° C. oven for 1, 4, and 6 hours, where sericin extraction was completed at 100° C. for 60 min.

FIGS. 12A-12D are photographs showing dissolved silk in 60° C. LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 13A-13D are photographs showing dissolved silk in 60° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 14A-14D are photographs showing dissolved silk in 60° C. LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 15A-15D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 16A-16D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 17A-17D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 18A-18D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 19A-19D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 20A-20D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 21A-21D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied time).

FIGS. 22A-22D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

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FIGS. 23A-23D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 24A-24D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 80° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 25A-25D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 80° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 26A-26D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 80° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 27A-27D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 100° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 28A-28D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 100° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 29A-29D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 100° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 30A-30D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 120° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 31A-31D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 120° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIG. 32A-32D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 120° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIG. 33 is a flow chart showing an embodiment for producing a silk film of the present disclosure from a silk solution of the present disclosure.

FIG. 34 summarizes an embodiment of parameters for a silk film drying study of the present disclosure.

FIG. 35 is a graph showing silk film drying times (under various air flow and temperature conditions).

FIGS. 36A and 36B show HPLC chromatograms from samples comprising vitamin C. FIG. 36A shows peaks from (1) a chemically stabilized sample of vitamin C at ambient conditions and (2) a sample of vitamin C taken after 1 hour at ambient conditions without chemical stabilization to prevent oxidation, where degradation products are visible. FIG. 36B shows peaks from two different embodiments of silk films of the present disclosure that were aged for at least 30 days at room temperature. No degradation products were visible.

FIGS. 37A-37D are photographs showing silk protein fragment-films of the present disclosure dried at room temperature for 48 hours with open air flow.

FIGS. 38A-38D are photographs showing silk protein fragment-films of the present disclosure dried at 40° C. in a convection oven for 8 hours with open air flow.

FIGS. 39A-39D are photographs showing silk protein fragment-films of the present disclosure dried at 40° C. in a convection oven for 48 hours with open air flow.

FIGS. 40A-40D are photographs showing silk protein fragment-films of the present disclosure dried at 40° C. in a convection oven for 48 hours in closed dish.

FIGS. 41A-41D are photographs showing silk protein fragment-films of the present disclosure dried at 54° C. in a convection oven for 8 hours in open dish.

FIGS. 42A-42D are photographs showing silk protein fragment-films of the present disclosure dried at 54° C. in a convection oven for 48 hours in open dish.

FIGS. 43A-43D are photographs showing silk protein fragment-films of the present disclosure dried at 54° C. in a film dryer for 8 hours in open dish.

FIGS. 44A-44D are photographs showing silk protein fragment-films of the present disclosure dried at 54° C. in a film dryer for 48 hours in open dish.

FIGS. 45A-45D are photographs showing silk protein fragment-films of the present disclosure dried at room temperature in a convection oven for 48 hours in open dish.

FIGS. 46A-46D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at room temperature for 48 hours with open air flow.

FIGS. 47A-47D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 40° C. in a convection oven for 8 hours with open air flow.

FIGS. 48A-48D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 40° C. in a convection oven for 48 hours with open air flow.

FIGS. 49A-49D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 40° C. in a convection oven for 48 hours in closed dish.

FIGS. 50A-50D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 54° C. in a convection oven for 8 hours in open dish.

FIGS. 51A-51D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 54° C. in a convection oven for 48 hours in open dish.

FIGS. 52A-52D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 54° C. in a film dryer for 8 hours in open dish.

FIGS. 53A-53D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at 54° C. in a film dryer for 48 hours in open dish.

FIGS. 54A-54D are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure dried at room temperature in a convection oven for 48 hours in open dish.

FIG. 55 is a table summarizing the LiBr and Sodium Carbonate (Na_2CO_3) concentration in silk protein solutions of the present disclosure.

FIG. 56 is a table summarizing the Na_2CO_3 concentration in silk protein fragment-films of the present disclosure.

FIG. 57 is a table summarizing the LiBr concentration in silk protein fragment-films of the present disclosure.

FIG. 58 is a table summarizing the LiBr and Na_2CO_3 concentration in silk protein solutions of the present disclosure.

FIG. 59 is a table summarizing the vitamin C concentration in silk protein fragment-films of the present disclosure.

FIG. 60 is a table summarizing the stability of vitamin C in chemically stabilized solutions.

FIG. 61 is a table summarizing the Molecular Weights of silk protein solutions of the present disclosure.

FIGS. 62A and 62B are graphs representing the effect of extraction volume on % mass loss.

FIG. 63 is a table summarizing the Molecular Weights of silk dissolved from different concentrations of LiBr and from different extraction and dissolution sizes.

FIG. 64 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. LiBr and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 65 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, boiling LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 66 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 60° C. LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 67 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. LiBr and 80° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 68 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 69 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 70 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 140° C. LiBr and 140° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 71 is a graph summarizing the effect of Extraction Temperature on Molecular Weight of silk processed under the conditions of 60 minute Extraction Time, 100° C. LiBr and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 72 is a graph summarizing the effect of LiBr Temperature on Molecular Weight of silk processed under the conditions of 60 minute Extraction Time, 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 73 is a graph summarizing the effect of LiBr Temperature on Molecular Weight of silk processed under the conditions of 30 minute Extraction Time, 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 74 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 minute Extraction Time, and 100° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 75 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 minute Extraction Time, and 100° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 76 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature

ture, 60 minute Extraction Time, and 140° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 77 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 minute Extraction Time, and 140° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 78 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 minute Extraction Time, and 80° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 79 is a graph summarizing the Molecular Weights of silk processed under varying conditions including Extraction Time, Extraction Temperature, Lithium Bromide (LiBr) Temperature, Oven Temperature for Dissolution, Oven Time for Dissolution.

FIG. 80 is a graph summarizing the Molecular Weights of silk processed under conditions in which Oven/Dissolution Temperature is equal to LiBr Temperature.

FIG. 81 is a graph representing the % Activity of Vitamin C in PureProC™ Gel.

FIGS. 82A-82C are photographs showing the effect of film drying on film color and physical integrity after storage (most dry (FIG. 82A), least dry (FIG. 82C)).

FIGS. 83A and 83B are photographs of a laser cut silk film.

FIG. 84 is a graph summarizing the quantity of vitamin C in a daily dose (i.e., the average amount of product used to cover a 25 cm² area of skin) of PureProC™ and competitor products over a 30 day period.

FIG. 85 is a graph summarizing the ease of use of PureProC™ collected in a user experience.

FIG. 86 is a summary of the initial benefits of PureProC™ observed by users and support of consumer knowledge.

FIG. 87 is a graph summarizing where trial participants used PureProC™ Smoothing Gel.

FIG. 88 is a summary of the benefits to the skin after using PureProC™ Smoothing Gel: Lemongrass by trial participants.

FIGS. 89A-89B are tables summarizing the effect of vitamin C with or without a vitamin C derivative on gelation.

FIG. 90 is a table summarizing the effect of vitamin C and vitamin C derivatives on the formation of silk films of the present disclosure.

FIGS. 91A-91B are tables summarizing the effect of vitamin C and caffeine on the formation of silk films of the present disclosure.

FIG. 92 is a table summarizing an embodiment of a caffeine gel of the present disclosure.

FIG. 93 is a table summarizing embodiments of preservative gels of the present disclosure.

FIGS. 94A-94C are tables summarizing embodiments of cosmetic serums of the present disclosure with varying additives and concentrations of components suitable for protection against ultraviolet radiation (UV).

FIGS. 95A-95C are tables summarizing embodiments of high concentration vitamin C gels of the present disclosure.

FIG. 96 is a table summarizing the results of various gels of the present disclosure to evaluate the possible microbial contamination in three different states of their use (intact, in-use, ending product).

FIG. 97 is a photograph of an embodiment of a foam product of the present disclosure suitable for protection against UV.

FIG. 98 is a photograph of an embodiment of a viscous liquid of the present disclosure suitable for protection against UV.

FIG. 99 is a photograph of an embodiment of a viscous liquid of the present disclosure suitable for protection against U.

FIG. 100 is a photograph an embodiment of a foam product of the present disclosure suitable for protection against UV.

While the above-identified drawings set forth presently disclosed embodiments, other embodiments are also contemplated, as noted in the discussion. This disclosure presents illustrative embodiments by way of representation and not limitation. Numerous other modifications and embodiments can be devised by those skilled in the art which fall within the scope and spirit of the principles of the presently disclosed embodiments.

DETAILED DESCRIPTION

Provided herein are methods for producing pure and highly scalable silk protein fragment (SPF) mixture solutions that may be used across multiple industries for a variety of applications. The solutions are generated from raw pure intact silk protein material and processed in order to remove any sericin and achieve the desired weight average molecular weight (MW) and polydispersity of the fragment mixture. Select method parameters may be altered to achieve distinct final silk protein fragment characteristics depending upon the intended use. The resulting final fragment solution is pure silk protein fragments and water with PPM to non-detectable levels of process contaminants, levels acceptable in the pharmaceutical, medical and consumer cosmetic markets. The concentration, size and polydispersity of silk protein fragments in the solution may further be altered depending upon the desired use and performance requirements. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, and have a polydispersity ranging from about 1.5 and about 3.0.

In an embodiment, the silk solutions of the present disclosure may be used to generate articles, such as silk films of various shapes and sizes by varying water content/concentration, or sold as a raw ingredient into the medical, consumer, or electronics markets. In an embodiment, the solutions may be used to generate articles, such as silk gels of varying gel and liquid consistencies by varying water content/concentration, or sold as a raw ingredient into the pharmaceutical, medical, consumer, or electronics markets. Depending on the silk solution utilized and the methods for casting the films or gels, various properties are achieved. The articles may be loaded with at least one therapeutic agent and/or at least one molecule.

As used herein, the terms “substantially sericin free” or “substantially devoid of sericin” refer to silk fibers in which a majority of the sericin protein has been removed. In an

embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 10.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 9.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 8.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 7.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 6.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 5.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.05% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.1% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 1.0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 1.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 2.0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 2.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content between about 0.01% (w/w) and about 0.1% (w/w). In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content below about 0.1% (w/w). In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content below about 0.05% (w/w). In an embodiment, when a silk source is added to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes, a degumming loss of about 26 wt. % to about 31 wt. % is obtained.

As used herein, the term “substantially homogeneous” may refer to pure silk fibroin-based protein fragments that are distributed in a normal distribution about an identified molecular weight. As used herein, the term “substantially homogeneous” may refer to an even distribution of additive, for example vitamin C, throughout a composition of the present disclosure.

As used herein, the term “substantially free of inorganic residuals” means that the composition exhibits residuals of 0.1% (w/w) or less. In an embodiment, substantially free of inorganic residuals refers to a composition that exhibits residuals of 0.05% (w/w) or less. In an embodiment, substantially free of inorganic residuals refers to a composition that exhibits residuals of 0.01% (w/w) or less. In an embodiment, the amount of inorganic residuals is between 0 ppm (“non-detectable” or “ND”) and 1000 ppm. In an embodiment, the amount of inorganic residuals is ND to about 500 ppm. In an embodiment, the amount of inorganic residuals

is ND to about 400 ppm. In an embodiment, the amount of inorganic residuals is ND to about 300 ppm. In an embodiment, the amount of inorganic residuals is ND to about 200 ppm. In an embodiment, the amount of inorganic residuals is ND to about 100 ppm. In an embodiment, the amount of inorganic residuals is between 10 ppm and 1000 ppm.

As used herein, the term “substantially free of organic residuals” means that the composition exhibits residuals of 0.1% (w/w) or less. In an embodiment, substantially free of organic residuals refers to a composition that exhibits residuals of 0.05% (w/w) or less. In an embodiment, substantially free of organic residuals refers to a composition that exhibits residuals of 0.01% (w/w) or less. In an embodiment, the amount of organic residuals is between 0 ppm (“non-detectable” or “ND”) and 1000 ppm. In an embodiment, the amount of organic residuals is ND to about 500 ppm. In an embodiment, the amount of organic residuals is ND to about 400 ppm. In an embodiment, the amount of organic residuals is ND to about 300 ppm. In an embodiment, the amount of organic residuals is ND to about 200 ppm. In an embodiment, the amount of organic residuals is ND to about 100 ppm. In an embodiment, the amount of organic residuals is between 10 ppm and 1000 ppm.

Compositions of the present disclosure exhibit “biocompatibility” meaning that the compositions are compatible with living tissue or a living system by not being toxic, injurious, or physiologically reactive and not causing immunological rejection. Such biocompatibility can be evidenced by participants topically applying compositions of the present disclosure on their skin for an extended period of time. In an embodiment, the extended period of time is about 3 days. In an embodiment, the extended period of time is about 7 days. In an embodiment, the extended period of time is about 14 days. In an embodiment, the extended period of time is about 21 days. In an embodiment, the extended period of time is about 30 days. In an embodiment, the extended period of time is selected from the group consisting of about 1 month, about 2 months, about 3 months, about 4 months, about 5 months, about 6 months, about 7 months, about 8 months, about 9 months, about 10 months, about 11 months, about 12 months, and indefinitely.

Compositions of the present disclosure are “hypoallergenic” meaning that they are relatively unlikely to cause an allergic reaction. Such hypoallergenicity can be evidenced by participants topically applying compositions of the present disclosure on their skin for an extended period of time. In an embodiment, the extended period of time is about 3 days. In an embodiment, the extended period of time is about 7 days. In an embodiment, the extended period of time is about 14 days. In an embodiment, the extended period of time is about 21 days. In an embodiment, the extended period of time is about 30 days. In an embodiment, the extended period of time is selected from the group consisting of about 1 month, about 2 months, about 3 months, about 4 months, about 5 months, about 6 months, about 7 months, about 8 months, about 9 months, about 10 months, about 11 months, about 12 months, and indefinitely.

In an embodiment, a solution of the present disclosure is contacted with a therapeutic agent and/or a molecule prior to forming the article. In an embodiment, molecules include, but are not limited to, antioxidants and enzymes. In an embodiment, molecules include, but are not limited to, Selenium, Ubiquinone derivatives, Thiol-based antioxidants, Saccharide-containing antioxidants, Polyphenols, Botanical extracts, Caffeic acid, Apigenin, Pycnogenol, Resveratrol, Folic acid, Vitamin b12, Vitamin b6, Vitamin b3, Vitamin E, Vitamin C and derivatives thereof, Vitamin D,

Vitamin A, Astaxathin, Lutein, Lycopene, Essential fatty acids (omegas 3 and 6), Iron, Zinc, magnesium, Flavonoids (soy, Curcumin, Silymarin, Pycnongeol), Growth factors, aloe, hyaluronic acid, extracellular matrix proteins, cells, nucleic acids, biomarkers, biological reagents, zinc oxide, benzoyl peroxide, retinoids, titanium, allergens in a known dose (for sensitization treatment), essential oils including, but not limited to, lemongrass or rosemary oil, and fragrances. Therapeutic agents include, but are not limited to, small molecules, drugs, proteins, peptides and nucleic acids. In an embodiment, a silk film of the present disclosure includes a molecule that is a vitamin, such as vitamin C, vitamin A and vitamin E. In an embodiment, a solution of the present disclosure is contacted with an allergen of known quantity prior to forming the article. Allergens include but are not limited to milk, eggs, peanuts, tree nuts, fish, shellfish, soy and wheat. Known doses of allergen loaded within a silk article can be released at a known rate for controlled exposure allergy study, tests and sensitization treatment.

In an embodiment, a solution of the present disclosure is used to create an article with microneedles by standard methods known to one in the art for controlled delivery of molecules or therapeutic agents to or through the skin.

As used herein, the term "fibroin" includes silkworm fibroin and insect or spider silk protein. In an embodiment, fibroin is obtained from *Bombyx mori*.

FIG. 1 is a flow chart showing various embodiments for producing pure silk fibroin-based protein fragments (SPFs) of the present disclosure. It should be understood that not all of the steps illustrated are necessarily required to fabricate all silk solutions of the present disclosure. As illustrated in FIG. 1, step A, cocoons (heat-treated or non-heat-treated), silk fibers, silk powder or spider silk can be used as the silk source. If starting from raw silk cocoons from *Bombyx mori*, the cocoons can be cut into small pieces, for example pieces of approximately equal size, step B1. The raw silk is then extracted and rinsed to remove any sericin, step C1a. This results in substantially sericin free raw silk. In an embodiment, water is heated to a temperature between 84° C. and 100° C. (ideally boiling) and then Na₂CO₃ (sodium carbonate) is added to the boiling water until the Na₂CO₃ is completely dissolved. The raw silk is added to the boiling water/Na₂CO₃ (100° C.) and submerged for approximately 15-90 minutes, where boiling for a longer time results in smaller silk protein fragments. In an embodiment, the water volume equals about 0.4× raw silk weight and the Na₂CO₃ volume equals about 0.848× raw silk weight. In an embodiment, the water volume equals 0.1× raw silk weight and the Na₂CO₃ volume is maintained at 2.12 g/L. This is demonstrated in FIG. 62A and FIG. 62B: silk mass (x-axis) was varied in the same volume of extraction solution (i.e., the same volume of water and concentration of Na₂CO₃) achieving sericin removal (substantially sericin free) as demonstrated by an overall silk mass loss of 26 to 31 percent (y-axis). Subsequently, the water dissolved Na₂CO₃ solution is drained and excess water/Na₂CO₃ is removed from the silk fibroin fibers (e.g., ring out the fibroin extract by hand, spin cycle using a machine, etc.). The resulting silk fibroin extract is rinsed with warm to hot water to remove any remaining adsorbed sericin or contaminate, typically at a temperature range of about 40° C. to about 80° C., changing the volume of water at least once (repeated for as many times as required). The resulting silk fibroin extract is a substantially sericin-depleted silk fibroin. In an embodiment, the resulting silk fibroin extract is rinsed with water at a temperature of about 60° C. In an embodiment, the volume

of rinse water for each cycle equals 0.1 L to 0.2 L× raw silk weight. It may be advantageous to agitate, turn or circulate the rinse water to maximize the rinse effect. After rinsing, excess water is removed from the extracted silk fibroin fibers (e.g., ring out fibroin extract by hand or using a machine). Alternatively, methods known to one skilled in the art such as pressure, temperature, or other reagents or combinations thereof may be used for the purpose of sericin extraction. Alternatively, the silk gland (100% sericin free silk protein) can be removed directly from a worm. This would result in liquid silk protein, without any alteration of the protein structure, free of sericin.

The extracted fibroin fibers are then allowed to dry completely. FIG. 3 is a photograph showing dry extracted silk fibroin. Once dry, the extracted silk fibroin is dissolved using a solvent added to the silk fibroin at a temperature between ambient and boiling, step C1b. In an embodiment, the solvent is a solution of Lithium bromide (LiBr) (boiling for LiBr is 140° C.). Alternatively, the extracted fibroin fibers are not dried but wet and placed in the solvent; solvent concentration can then be varied to achieve similar concentrations as to when adding dried silk to the solvent. The final concentration of LiBr solvent can range from 0.1M to 9.3M. FIG. 63 is a table summarizing the Molecular Weights of silk dissolved from different concentrations of Lithium Bromide (LiBr) and from different extraction and dissolution sizes. Complete dissolution of the extracted fibroin fibers can be achieved by varying the treatment time and temperature along with the concentration of dissolving solvent. Other solvents may be used including, but not limited to, phosphate phosphoric acid, calcium nitrate, calcium chloride solution or other concentrated aqueous solutions of inorganic salts. To ensure complete dissolution, the silk fibers should be fully immersed within the already heated solvent solution and then maintained at a temperature ranging from about 60° C. to about 140° C. for 1-168 hrs. In an embodiment, the silk fibers should be fully immersed within the solvent solution and then placed into a dry oven at a temperature of about 100° C. for about 1 hour.

The temperature at which the silk fibroin extract is added to the LiBr solution (or vice versa) has an effect on the time required to completely dissolve the fibroin and on the resulting molecular weight and polydispersity of the final SPF mixture solution. In an embodiment, silk solvent solution concentration is less than or equal to 20% w/v. In addition, agitation during introduction or dissolution may be used to facilitate dissolution at varying temperatures and concentrations. The temperature of the LiBr solution will provide control over the silk protein fragment mixture molecular weight and polydispersity created. In an embodiment, a higher temperature will more quickly dissolve the silk offering enhanced process scalability and mass production of silk solution. In an embodiment, using a LiBr solution heated to a temperature between 80° C.-140° C. reduces the time required in an oven in order to achieve full dissolution. Varying time and temperature at or above 60° C. of the dissolution solvent will alter and control the MW and polydispersity of the SPF mixture solutions formed from the original molecular weight of the native silk fibroin protein.

Alternatively, whole cocoons may be placed directly into a solvent, such as LiBr, bypassing extraction, step B2. This requires subsequent filtration of silk worm particles from the silk and solvent solution and sericin removal using methods known in the art for separating hydrophobic and hydrophilic proteins such as a column separation and/or chromatography, ion exchange, chemical precipitation with salt and/or pH, and or enzymatic digestion and filtration or extraction,

all methods are common examples and without limitation for standard protein separation methods, step C2. Non-heat treated cocoons with the silkworm removed, may alternatively be placed into a solvent such as LiBr, bypassing extraction. The methods described above may be used for sericin separation, with the advantage that non-heat treated cocoons will contain significantly less worm debris.

Dialysis may be used to remove the dissolution solvent from the resulting dissolved fibroin protein fragment solution by dialyzing the solution against a volume of water, step E1. Pre-filtration prior to dialysis is helpful to remove any debris (i.e., silk worm remnants) from the silk and LiBr solution, step D. In one example, a 3 μm or 5 μm filter is used with a flow-rate of 200-300 mL/min to filter a 0.1% to 1.0% silk-LiBr solution prior to dialysis and potential concentration if desired. A method disclosed herein, as described above, is to use time and/or temperature to decrease the concentration from 9.3M LiBr to a range from 0.1M to 9.3M to facilitate filtration and downstream dialysis, particularly when considering creating a scalable process method. Alternatively, without the use of additional time or temperate, a 9.3M LiBr-silk protein fragment solution may be diluted with water to facilitate debris filtration and dialysis. The result of dissolution at the desired time and temperate filtration is a translucent particle-free room temperature shelf-stable silk protein fragment-LiBr solution of a known MW and polydispersity. It is advantageous to change the dialysis water regularly until the solvent has been removed (e.g., change water after 1 hour, 4 hours, and then every 12 hours for a total of 6 water changes). The total number of water volume changes may be varied based on the resulting concentration of solvent used for silk protein dissolution and fragmentation. After dialysis, the final silk solution may be further filtered to remove any remaining debris (i.e., silk worm remnants).

Alternatively, Tangential Flow Filtration (TFF), which is a rapid and efficient method for the separation and purification of biomolecules, may be used to remove the solvent from the resulting dissolved fibroin solution, step E2. TFF offers a highly pure aqueous silk protein fragment solution and enables scalability of the process in order to produce large volumes of the solution in a controlled and repeatable manner. The silk and LiBr solution may be diluted prior to TFF (20% down to 0.1% silk in either water or LiBr). Pre-filtration as described above prior to TFF processing may maintain filter efficiency and potentially avoids the creation of silk gel boundary layers on the filter's surface as the result of the presence of debris particles. Pre-filtration prior to TFF is also helpful to remove any remaining debris (i.e., silk worm remnants) from the silk and LiBr solution that may cause spontaneous or long-term gelation of the resulting water only solution, step D. TFF, recirculating or single pass, may be used for the creation of water-silk protein fragment solutions ranging from 0.1% silk to 30.0% silk (more preferably, 0.1%-6.0% silk). Different cutoff size TFF membranes may be required based upon the desired concentration, molecular weight and polydispersity of the silk protein fragment mixture in solution. Membranes ranging from 1-100 kDa may be necessary for varying molecular weight silk solutions created for example by varying the length of extraction boil time or the time and temperate in dissolution solvent (e.g., LiBr). In an embodiment, a TFF 5 or 10 kDa membrane is used to purify the silk protein fragment mixture solution and to create the final desired silk-to-water ratio. As well, TFF single pass, TFF, and other methods known in the art, such as a falling film evaporator, may be used to concentrate the solution following removal

of the dissolution solvent (e.g., LiBr) (with resulting desired concentration ranging from 0.1% to 30% silk). This can be used as an alternative to standard HFIP concentration methods known in the art to create a water-based solution. A larger pore membrane could also be utilized to filter out small silk protein fragments and to create a solution of higher molecular weight silk with and/or without tighter polydispersity values. FIG. 61 is a table summarizing Molecular Weights for some embodiments of silk protein solutions of the present disclosure. Silk protein solution processing conditions were as follows: 100° C. extraction for 20 min, room temperature rinse, LiBr in 60° C. oven for 4-6 hours. TFF processing conditions for water-soluble films were as follows: 100° C. extraction for 60 min, 60° C. rinse, 100° C. LiBr in 100° C. oven for 60 min. FIGS. 67-78 further demonstrate manipulation of extraction time, LiBr dissolution conditions, and TFF processing and resultant example molecular weights and polydispersities. These examples are not intended to be limiting, but rather to demonstrate the potential of specifying parameters for specific molecular weight silk fragment solutions.

An assay for LiBr and Na_2CO_3 detection was performed using an HPLC system equipped with evaporative light scattering detector (ELSD). The calculation was performed by linear regression of the resulting peak areas for the analyte plotted against concentration. More than one sample of a number of formulations of the present disclosure was used for sample preparation and analysis. Generally, four samples of different formulations were weighed directly in a 10 mL volumetric flask. The samples were suspended in 5 mL of 20 mM ammonium formate (pH 3.0) and kept at 2-8° C. for 2 hours with occasional shaking to extract analytes from the film. After 2 hours the solution was diluted with 20 mM ammonium formate (pH 3.0). The sample solution from the volumetric flask was transferred into HPLC vials and injected into the HPLC-ELSD system for the estimation of sodium carbonate and lithium bromide.

The analytical method developed for the quantitation of Na_2CO_3 and LiBr in silk protein formulations was found to be linear in the range 10-165 $\mu\text{g/mL}$, with RSD for injection precision as 2% and 1% for area and 0.38% and 0.19% for retention time for sodium carbonate and lithium bromide respectively. The analytical method can be applied for the quantitative determination of sodium carbonate and lithium bromide in silk protein formulations.

The final silk protein fragment solution, as shown in FIG. 4, is pure silk protein fragments and water with PPM to undetectable levels of particulate debris and/or process contaminants, including LiBr and Na_2CO_3 . FIG. 55 and FIG. 58 are tables summarizing LiBr and Na_2CO_3 concentrations in solutions of the present disclosure. In FIG. 55, the processing conditions included 100° C. extraction for 60 min, 60° C. rinse, 100° C. LiBr in 100° C. oven for 60 min. TFF conditions including pressure differential and number of dia-filtration volumes were varied. In FIG. 58, the processing conditions included 100° C. boil for 60 min, 60° C. rinse, LiBr in 60° C. oven for 4-6 hours. In an embodiment, a SPF composition of the present disclosure is not soluble in an aqueous solution due to the crystallinity of the protein. In an embodiment, a SPF composition of the present disclosure is soluble in an aqueous solution. In an embodiment, the SPFs of a composition of the present disclosure include a crystalline portion of about two-thirds and an amorphous region of about one-third. In an embodiment, the SPFs of a composition of the present disclosure include a crystalline portion of about one-half and an amorphous region of about one-half. In an embodiment, the SPFs of a composition of

the present disclosure include a 99% crystalline portion and a 1% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 95% crystalline portion and a 5% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 90% crystalline portion and a 10% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 85% crystalline portion and a 15% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 80% crystalline portion and a 20% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 75% crystalline portion and a 25% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 70% crystalline portion and a 30% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 65% crystalline portion and a 35% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 60% crystalline portion and a 40% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 50% crystalline portion and a 50% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 40% crystalline portion and a 60% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 35% crystalline portion and a 65% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 30% crystalline portion and a 70% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 25% crystalline portion and a 75% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 20% crystalline portion and a 80% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 15% crystalline portion and a 85% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 10% crystalline portion and a 90% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 5% crystalline portion and a 95% amorphous region. In an embodiment, the SPF of a composition of the present disclosure include a 1% crystalline portion and a 99% amorphous region.

A unique feature of the SPF compositions of the present disclosure are shelf stability (they will not slowly or spontaneously gel when stored in an aqueous solution and there is no aggregation of fragments and therefore no increase in molecular weight over time), from 10 days to 3 years depending on storage conditions, percent silk, and number of shipments and shipment conditions. Additionally pH may be altered to extend shelf-life and/or support shipping conditions by preventing premature folding and aggregation of the silk. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 2 weeks at room temperature (RT). In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 4 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 6 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 8 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 10 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 12 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability ranging from about 4 weeks to about 52 weeks at RT. Table

1 below shows shelf stability test results for embodiments of SPF compositions of the present disclosure.

TABLE 1

Shelf Stability of SPF Compositions of the Present Disclosure		
% Silk	Temperature	Time to Gelation
2	RT	4 weeks
2	4 C.	>9 weeks
4	RT	4 weeks
4	4 C.	>9 weeks
6	RT	2 weeks
6	4 C.	>9 weeks

A known additive such as a vitamin (e.g., vitamin C) can be added to a SPF composition of the present disclosure to create a gel that is stable from 10 days to 3 years at room temperature (RT). Both examples, a SPF composition and the same with an additive, can be lyophilized for enhanced storage control ranging from 10 days to 10 years depending on storage and shipment conditions. The lyophilized silk powder can also be used as a raw ingredient in the medical, consumer, and electronic markets. Additionally, lyophilized silk powder can be resuspended in water, HFIP, or organic solution following storage to create silk solutions of varying concentrations, including higher concentration solutions than those produced initially. In another embodiment, the silk fibroin-based protein fragments are dried using a roto-therm evaporator or other methods known in the art for creating a dry protein form containing less than 10% water by mass.

Either the silk fragment-water solutions or the lyophilized silk protein fragment mixture can be sterilized following standard methods in the art not limited to filtration, heat, radiation or e-beam. It is anticipated that the silk protein fragment mixture, because of its shorter protein polymer length, will withstand sterilization better than intact silk protein solutions described in the art. Additionally, silk articles created from the SPF mixtures described herein may be sterilized as appropriate to application. For example, a silk film loaded with a molecule to be used in medical applications with an open wound/incision, may be sterilized standard methods such as by radiation or e-beam.

FIG. 2 is a flow chart showing various parameters that can be modified during the process of producing a silk protein fragment solution of the present disclosure during the extraction and the dissolution steps. Select method parameters may be altered to achieve distinct final solution characteristics depending upon the intended use, e.g., molecular weight and polydispersity. It should be understood that not all of the steps illustrated are necessarily required to fabricate all silk solutions of the present disclosure.

In an embodiment, a process for producing a silk protein fragment solution of the present disclosure includes forming pieces of silk cocoons from the *Bombyx mori* silk worm; extracting the pieces at about 100° C. in a solution of water and Na₂CO₃ for about 60 minutes, wherein a volume of the water equals about 0.4× raw silk weight and the amount of Na₂CO₃ is about 0.848× the weight of the pieces to form a silk fibroin extract; triple rinsing the silk fibroin extract at about 60° C. for about 20 minutes per rinse in a volume of rinse water, wherein the rinse water for each cycle equals about 0.2 L× the weight of the pieces; removing excess water from the silk fibroin extract; drying the silk fibroin extract; dissolving the dry silk fibroin extract in a LiBr solution, wherein the LiBr solution is first heated to about 100° C. to create a silk and LiBr solution and maintained; placing the silk and LiBr solution in a dry oven at about 100° C. for about 60 minutes to achieve complete dissolution and

further fragmentation of the native silk protein structure into mixture with desired molecular weight and polydispersity; filtering the solution to remove any remaining debris from the silkworm; diluting the solution with water to result in a 1% silk solution; and removing solvent from the solution using Tangential Flow Filtration (TFF). In an embodiment, a 10 kDa membrane is utilized to purify the silk solution and create the final desired silk-to-water ratio. TFF can then be used to further concentrate the pure silk solution to a concentration of 2% silk to water.

Each process step from raw cocoons to dialysis is scalable to increase efficiency in manufacturing. Whole cocoons are currently purchased as the raw material, but pre-cleaned cocoons or non-heat treated cocoons, where worm removed leaves minimal debris, have also been used. Cutting and cleaning the cocoons is a manual process, however for scalability this process could be made less labor intensive by, for example, using an automated machine in combination with compressed air to remove the worm and any particulates, or using a cutting mill to cut the cocoons into smaller pieces. The extraction step, currently performed in small batches, could be completed in a larger vessel, for example an industrial washing machine where temperatures at or in between 60° C. to 100° C. can be maintained. The rinsing step could also be completed in the industrial washing machine, eliminating the manual rinse cycles. Dissolution of the silk in LiBr solution could occur in a vessel other than a convection oven, for example a stirred tank reactor. Dialyzing the silk through a series of water changes is a manual and time intensive process, which could be accelerated by changing certain parameters, for example diluting the silk solution prior to dialysis. The dialysis process could be scaled for manufacturing by using semi-automated equipment, for example a tangential flow filtration system.

Varying extraction (i.e., time and temperature), LiBr (i.e., temperature of LiBr solution when added to silk fibroin extract or vice versa) and dissolution (i.e., time and temperature) parameters results in solvent and silk solutions with different viscosities, homogeneities, and colors (see FIGS. 5-32). Increasing the temperature for extraction, lengthening the extraction time, using a higher temperature LiBr solution at emersion and over time when dissolving the silk and increasing the time at temperature (e.g., in an oven as shown here, or an alternative heat source) all resulted in less viscous and more homogeneous solvent and silk solutions. While almost all parameters resulted in a viable silk solution, methods that allow complete dissolution to be achieved in fewer than 4 to 6 hours are preferred for process scalability.

FIGS. 5-10 show photographs of four different silk extraction combinations tested: 90° C. 30 min, 90° C. 60 min, 100° C. 30 min, and 100° C. 60 min. Briefly, 9.3 M LiBr was prepared and allowed to sit at room temperature for at least 30 minutes. 5 mL of LiBr solution was added to 1.25 g of silk and placed in the 60° C. oven. Samples from each set were removed at 4, 6, 8, 12, 24, 168 and 192 hours. The remaining sample was photographed.

FIGS. 11-23 show photographs of four different silk extraction combinations tested: 90° C. 30 min, 90° C. 60 min, 100° C. 30 min, and 100° C. 60 min. Briefly, 9.3 M LiBr solution was heated to one of four temperatures: 60° C., 80° C., 100° C. or boiling. 5 mL of hot LiBr solution was added to 1.25 g of silk and placed in the 60° C. oven. Samples from each set were removed at 1, 4 and 6 hours. The remaining sample was photographed.

FIGS. 24-32 show photographs of four different silk extraction combinations tested: Four different silk extraction combinations were used: 90° C. 30 min, 90° C. 60 min, 100° C. 30 min, and 100° C. 60 min. Briefly, 9.3 M LiBr solution was heated to one of four temperatures: 60° C., 80° C., 100°

C. or boiling. 5 mL of hot LiBr solution was added to 1.25 g of silk and placed in the oven at the same temperature of the LiBr. Samples from each set were removed at 1, 4 and 6 hours. 1 mL of each sample was added to 7.5 mL of 9.3 M LiBr and refrigerated for viscosity testing. The remaining sample was photographed.

Molecular weight of the silk protein fragments may be controlled based upon the specific parameters utilized during the extraction step, including extraction time and temperature; specific parameters utilized during the dissolution step, including the LiBr temperature at the time of submersion of the silk in to the lithium bromide and time that the solution is maintained at specific temperatures; and specific parameters utilized during the filtration step. By controlling process parameters using the disclosed methods, it is possible to create SPF mixture solutions with polydispersity equal to or lower than 2.5 at a variety of different molecular weight ranging from 5 kDa to 200 kDa, more preferably between 10 kDa and 80 kDa. By altering process parameters to achieve silk solutions with different molecular weights, a range of fragment mixture end products, with desired polydispersity of equal to or less than 2.5 may be targeted based upon the desired performance requirements. For example, a lower molecular weight silk film containing a drug may have a faster release rate compared to a higher molecular weight film making it more ideal for a daily delivery vehicle in consumer cosmetics. Additionally, SPF mixture solutions with a polydispersity of greater than 2.5 can be achieved. Further, two solutions with different average molecular weights and polydispersities can be mixed to create combination solutions. Alternatively, a liquid silk gland (100% sericin free silk protein) that has been removed directly from a worm could be used in combination with any of the SPF mixture solutions of the present disclosure. Molecular weight of the pure silk fibroin-based protein fragment composition was determined using High Pressure Liquid Chromatography (HPLC) with a Refractive Index Detector (RID). Polydispersity was calculated using Cirrus GPC Online GPC/SEC Software Version 3.3 (Agilent).

Parameters were varied during the processing of raw silk cocoons into silk solution. Varying these parameters affected the MW of the resulting silk solution. Parameters manipulated included (i) time and temperature of extraction, (ii) temperature of LiBr, (iii) temperature of dissolution oven, and (iv) dissolution time. Molecular weight was determined with mass spec as shown in FIGS. 64-80.

Experiments were carried out to determine the effect of varying the extraction time. FIGS. 64-70 are graphs showing these results, and Tables 2-8 summarize the results. Below is a summary:

A sericin extraction time of 30 minutes resulted in larger MW than a sericin extraction time of 60 minutes

MW decreases with time in the oven

140° C. LiBr and oven resulted in the low end of the confidence interval to be below a MW of 9500 Da

30 min extraction at the 1 hour and 4 hour time points have undigested silk

30 min extraction at the 1 hour time point resulted in a significantly high molecular weight with the low end of the confidence interval being 35,000 Da

The range of MW reached for the high end of the confidence interval was 18000 to 216000 Da (important for offering solutions with specified upper limit)

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TABLE 2

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. Lithium Bromide (LiBr) and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

Boil Time	Oven		Average Mw	Std dev	Confidence Interval	PD	
	Time	Time					
30	1		57247	12780	35093	93387	1.63
60	1		31520	1387	11633	85407	2.71
30	4		40973	2632	14268	117658	2.87
60	4		25082	1248	10520	59803	2.38
30	6		25604	1405	10252	63943	2.50
60	6		20980	1262	10073	43695	2.08

TABLE 3

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, boiling Lithium Bromide (LiBr) and 60° C. Oven Dissolution for 4 hr.

Sample	Boil Time	Average Mw	Std dev	Confidence Interval	PD	
30 min, 4 hr	30	49656	4580	17306	142478	2.87
60 min, 4 hr	60	30042	1536	11183	80705	2.69

TABLE 4

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60° C. Lithium Bromide (LiBr) and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD	
30 min, 1 hr	30	1	58436		22201	153809	2.63
60 min, 1 hr	60	1	31700		11931	84224	2.66
30 min, 4 hr	30	4	61956.5	13337	21463	178847	2.89
60 min, 4 hr	60	4	25578.5	2446	9979	65564	2.56

TABLE 5

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. Lithium Bromide (LiBr) and 80° C. Oven Dissolution for 6 hr.

Sample	Boil Time	Average Mw	Std dev	Confidence Interval	PD	
30 min, 6 hr	30	63510		18693	215775	3.40
60 min, 6 hr	60	25164	238	9637	65706	2.61

TABLE 6

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. Lithium Bromide (LiBr) and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD	
30 min, 4 hr	30	4	59202	14028	19073	183760	3.10
60 min, 4 hr	60	4	26312.5	637	10266	67442	2.56
30 min, 6 hr	30	6	46824		18076	121293	2.59
60 min, 6 hr	60	6	26353		10168	68302	2.59

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TABLE 7

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. Lithium Bromide (LiBr) and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval		PD
					Lower	Upper	
30 min, 4 hr	30	4	47853		19758	115900	2.42
60 min, 4 hr	60	4	25082	1248	10520	59804	2.38
30 min, 6 hr	30	6	55421	8992	19153	160366	2.89
60 min, 6 hr	60	6	20980	1262	10073	43694	2.08

TABLE 8

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 140° C. Lithium Bromide (LiBr) and 140° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD	
30 min, 4 hr	30	4	9024.5	1102	4493	18127	2.00865
60 min, 4 hr	60	4	15548		6954	34762	2.2358
30 min, 6 hr	30	6	13021		5987	28319	2.1749
60 min, 6 hr	60	6	10888		5364	22100	2.0298

Experiments were carried out to determine the effect of varying the extraction temperature. FIG. 71 is a graph showing these results, and Table 9 summarizes the results. Below is a summary:

Sericin extraction at 90° C. resulted in higher MW than sericin extraction at 100° C. extraction

Both 90° C. and 100° C. show decreasing MW over time in the oven

TABLE 9

The effect of extraction temperature (90° C. vs. 100° C.) on molecular weight of silk processed under the conditions of 60 min. Extraction Temperature, 100° C. Lithium Bromide (LiBr) and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD	
90 C., 4 hr	60	4	37308	4204	13368	104119	2.79
100 C., 4 hr	60	4	25082	1248	10520	59804	2.38
90 C., 6 hr	60	6	34224	1135	12717	92100	2.69
100 C., 6 hr	60	6	20980	1262	10073	43694	2.08

Experiments were carried out to determine the effect of varying the Lithium Bromide (LiBr) temperature when added to silk. FIGS. 72-73 are graphs showing these results, and Tables 10-11 summarize the results. Below is a summary:

No impact on MW or confidence interval (all CI ~10500-6500 Da)

Studies illustrated that the temperature of LiBr-silk dissolution, as LiBr is added and begins dissolving, rapidly drops below the original LiBr temperature due to the majority of the mass being silk at room temp

TABLE 10

The effect of Lithium Bromide (LiBr) temperature on molecular weight of silk processed under the conditions of 60 min. Extraction Time., 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	LiBr Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60 C. LiBr, 1 hr	60	1	31700		11931 84223	2.66
100 C. LiBr, 1 hr	100	1	27907	200	10735 72552	2.60
RT LiBr, 4 hr	RT	4	29217	1082	10789 79119	2.71
60 C. LiBr, 4 hr	60	4	25578	2445	9978 65564	2.56
80 C. LiBr, 4 hr	80	4	26312	637	10265 67441	2.56
100 C. LiBr, 4 hr	100	4	27681	1729	11279 67931	2.45
Boil LiBr, 4 hr	Boil	4	30042	1535	11183 80704	2.69
RT LiBr, 6 hr	RT	6	26543	1893	10783 65332	2.46
80 C. LiBr, 6 hr	80	6	26353		10167 68301	2.59
100 C. LiBr, 6 hr	100	6	27150	916	11020 66889	2.46

TABLE 11

The effect of Lithium Bromide (LiBr) temperature on molecular weight of silk processed under the conditions of 30 min. Extraction Time, 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	LiBr Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60 C. LiBr, 4 hr	60	4	61956	13336	21463 178847	2.89
80 C. LiBr, 4 hr	80	4	59202	14027	19073 183760	3.10
100 C. LiBr, 4 hr	100	4	47853		19757 115899	2.42
80 C. LiBr, 6 hr	80	6	46824		18075 121292	2.59
100 C. LiBr, 6 hr	100	6	55421	8991	19152 160366	2.89

Experiments were carried out to determine the effect of oven/dissolution temperature. FIGS. 74-78 are graphs showing these results, and Tables 12-16 summarize the results. Below is a summary:

Oven temperature has less of an effect on 60 min extracted silk than 30 min extracted silk. Without wishing to be bound by theory, it is believed that the 30 min silk is less degraded during extraction and therefore the oven temperature has more of an effect on the larger MW, less degraded portion of the silk.

For 60° C. vs. 140° C. oven the 30 min extracted silk showed a very significant effect of lower MW at higher oven temp, while 60 min extracted silk had an effect but much less

The 140° C. oven resulted in a low end in the confidence interval at ~6000 Da

TABLE 12

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 min. Extraction Time, and 100° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30	60	4	47853	19758	115900	2.42
30	100	4	40973	2632	14268 117658	2.87
30	60	6	55421	8992	19153 160366	2.89
30	100	6	25604	1405	10252 63943	2.50

TABLE 13

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 100° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60	60	1	27908	200	10735 72552	2.60
60	100	1	31520	1387	11633 85407	2.71
60	60	4	27681	1730	11279 72552	2.62
60	100	4	25082	1248	10520 59803	2.38
60	60	6	27150	916	11020 66889	2.46
60	100	6	20980	1262	10073 43695	2.08

TABLE 14

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 140° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60	60	4	30042	1536	11183 80705	2.69
60	140	4	15548		7255 33322	2.14

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TABLE 15

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 min. Extraction Time, and 140° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30	60	4	49656	4580	17306 142478	2.87
30	140	4	9025	1102	4493 18127	2.01
30	60	6	59383	11640	17641 199889	3.37
30	140	6	13021		5987 28319	2.17

TABLE 16

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 80° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60	60	4	26313	637	10266 67442	2.56
60	80	4	30308	4293	12279 74806	2.47
60	60	6	26353	10168	68302 2.59	
60	80	6	25164	238	9637 65706	2.61

In an embodiment, the methods disclosed herein result in a solution with characteristics that can be controlled during manufacturing, including, but not limited to: MW—may be varied by changing extraction and/or dissolution time and temp (e.g., LiBr temperature), pressure, and filtration (e.g., size exclusion chromatography); Structure—removal or cleavage of heavy or light chain of the fibroin protein polymer; Purity—hot water rinse temperature for improved sericin removal or filter capability for improved particulate removal that adversely affects shelf stability of the silk fragment protein mixture solution; Color—the color of the solution can be controlled with, for example, LiBr temp and time; Viscosity; Clarity; and Stability of solution. The resultant pH of the solution is typically about 7 and can be altered using an acid or base as appropriate to storage requirements.

The above-described SPF mixture solutions may be utilized to produce a pure silk protein fragment-film or pure silk protein fragment-gel for numerous applications (e.g., delivery of a drug, vitamin, antioxidant, etc. to the skin). FIG. 33 is a flow chart showing an embodiment for producing a silk film of the present disclosure from a silk solution of the present disclosure. In step A, a silk solution of the present disclosure is chosen, and then at least one molecule or therapeutic agent is added directly to the silk solution prior to gel or film processing, step B. When producing a silk film, the silk solution with additive(s) may be cast directly onto a shaped mold to achieve a unique film shape (e.g., silicone mold) or the silk solution may be cast as a sheet and then subsequently cut or punched into a variety of shapes, with a variety of cutting techniques, including, but not limited to cutting with a rotary blade or laser cutting for example (FIGS. 83A and 83B), depending upon the desired application, step C. If cast on a mold, for example silicone, the silicone mold may be heated on a laser-etched/patterned surface to create an impression that will be transferred to the final film. For example, the product logo could be transferred to the film, visible, but not palpable by hand, and used to show authenticity of the product. The concentration and/or mass of the final silk protein fragment film can be varied to control the film's degree of flexibility and confor-

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mity to different anatomical topographies. Altering the drying method for a silk film will also result in different final film characteristics. Applying airflow and/or heat impacts the properties of the film (e.g., brittleness, number of bubbles, curling, solubility, surface appearance), step D. Additionally, the percent moisture within the film at the time of packaging will impact stability over time with too much moisture resulting in yellowing of the films with time (FIGS. 82A-82C). In some embodiments, films ideally may have between about 2 to about 20% water content at completion of drying. It was observed that greater moisture content than 20% in the films will decrease shelf life. If films are not dry enough (that is they have greater than 20% water content) before packaging, they will yellow over time (2+ weeks). It is advised that films are dried in an incubator until the relative humidity in the incubator is less than the relative humidity in the surrounding area and no greater than 36%. Ambient humidity will have an effect on the ability to remove moisture and therefore, a tactile/audio test can be used to determine whether films are ready for packaging. In an embodiment, the test includes removal of a film from the drying system, slightly bending one end of the film and releasing it. If the film feels and sounds similar to a piece of paper or thin plastic, it is considered dry. If the film has not completed drying, it will be pliable and will make no noise upon bending and release. In an embodiment, the film is flexible without the need for process additives such as glycerin, such that a film that is 2.5 cm wide by 10 cm long can be bent in half so that opposite ends of the film can touch one another without the film breaking or cracking. A film of this same size can be bent in half along the length of the film to create a 45-degree angle without breaking or cracking the film.

The final silk protein fragment-film is pure with undetectable levels of particulate debris and/or process contaminants, including LiBr and Na₂CO₃. Alternatively, the final SPF mixture solution has less than 500 ppm process contaminants. FIG. 56 and FIG. 57 are tables summarizing LiBr and Na₂CO₃ concentrations in films (2% silk films air dried at RT) of the present disclosure. In FIG. 56, the processing conditions included 100° C. extraction for 20 min, RT rinse, LiBr in 60° C. oven for 4-6 hours. In FIG. 57, the processing conditions included 100° C. extraction for 20 min, RT rinse, LiBr in 60° C. oven for 4-6 hours.

In an embodiment, when producing a silk gel, an acid is used to help facilitate gelation. In an embodiment, when producing a silk gel that includes a neutral or a basic molecule and/or therapeutic agent, an acid can be added to facilitate gelation. In an embodiment, when producing a silk gel, increasing the pH (making the gel more basic) increases the shelf stability of the gel. In an embodiment, when producing a silk gel, increasing the pH (making the gel more basic) allows for a greater quantity of an acidic molecule to be loaded into the gel.

In an embodiment, natural additives may be added to the silk gel to further stabilize additives. For example, trace elements such as selenium or magnesium or L-methoinine can be used. Further, light-block containers can be added to further increase stability.

FIG. 34 summarizes an embodiment of parameters for a silk fragment-film drying study of the present disclosure. FIG. 35 is a graph showing silk fragment-film drying times (under various air flow and temperature conditions) based on the silk fragment-film drying study of FIG. 34. These studies indicate that airflow is an important parameter to consider for drying (i.e., samples in covered containers did not dry), temperature can be altered to alter drying rate (i.e., increased

temperature results in a faster rate of water removal) and that a steady-state of moisture content within the films can be obtained with a variety of parameters (i.e., from 24 to 48 hours, mass is consistent in uncovered samples regardless of temperature). Of note, the final properties of the film, for example brittleness, will vary with drying conditions. Alternatively, film drying rate may be accelerated by the use of an additive in the SPF solution, such as a surfactant or oil. These additives may be used with or without heat to alter drying rate and final film physical properties.

In an embodiment, the drying conditions of the SFP film are 24° C. in a forced air flow incubator for 12 to 48 hours depending on the number of films and ambient humidity. Under these drying conditions, a film that will not shrink more than 5 percent over time when stored in a foil pouch is created. Additionally, the film is homogeneous in composition and physical structure, with no sided-ness and an even distribution of additive, for example vitamin C, throughout.

In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 30% to about 100% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 35% to about 95% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 40% to about 90% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 45% to about 85% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 50% to about 80% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 55% to about 75% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in light retaining about 60% to about 70% of its activity after 30 days of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in a sealed airtight container or pouch that prevents light from contacting the film retaining about 80% to about 100% of its activity after 3 to 24 months of storage. In an embodiment, the silk protein fragment-film may stabilize vitamin C and derivatives thereof at room temperature when stored in a sealed airtight container or pouch that prevents light from contacting the film retaining about 80% to about 100% of its activity after about 3 to about 60 months of storage. In an embodiment, the silk protein fragment-film may release between 50% to 90% of active vitamin C and derivatives thereof within 20 mins when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 50% active vitamin C and derivatives thereof within 20 mins when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 60% active vitamin C and derivatives thereof within 20 mins when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 70% active vitamin C and derivatives thereof within 20 mins when adhered to dampened skin. In an embodiment, the silk protein

fragment-film may release at least 80% active vitamin C and derivatives thereof within 20 mins when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 90% active vitamin C and derivatives thereof within 20 mins when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release between 10% to 100% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 10% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 20% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 30% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 40% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 50% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 60% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 70% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 80% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. In an embodiment, the silk protein fragment-film may release at least 90% of active vitamin C and derivatives thereof within 5 mins to 8 hours when adhered to dampened skin. It is believed that exposure to higher temperatures for a longer period of time may break down the silk protein into more versatile silk protein fragment mixtures and/or disrupt any silk protein tertiary and/or secondary silk protein structure that could adversely affect shelf stability and/or performance of resulting structures (e.g., gels, films, foams, etc.) as well as reduces the number of heavy chains within the silk protein.

FIGS. 36A and 36B show two HPLC chromatograms from samples comprising vitamin C. The chromatogram on the left shows peaks from (1) a chemically stabilized sample of vitamin C at ambient conditions and (2) a sample of vitamin C taken after 1 hour at ambient conditions without chemical stabilization to prevent oxidation, where degradation products are visible. The chromatogram on the right shows peaks from two different embodiments of silk films of the present disclosure that were aged for at least 30 days at room temperature. No degradation products were visible. FIG. 59 is a table summarizing the vitamin C concentration in silk protein fragment-films (2% silk films air dried at RT) of the present disclosure. In FIG. 59 processing conditions included 100° C. extraction for 20 min, RT rinse, LiBr in 60° C. oven for 4-6 hours. FIG. 60 is a table summarizing the stability of vitamin C in chemically stabilized solutions. FIGS. 89A-89B are tables summarizing vitamin C stability in SPF gels without chemical stabilizers as compared to chemically stabilized vitamin C in competitive anti-aging skincare products. A gel cast at 20% total vitamin C additive concentration did not gel. Without wishing to be bound by theory, it appears there is a relationship between vitamin C concentration, silk concentration, and gelation. An increase in vitamin C at a given concentration of silk will result in a

longer time to gelation or inhibit gelation. This may be due to the vitamin C molecule physically blocking interaction between silk protein fragments or cross-linking of silk protein.

In an embodiment, the molecule or molecules are stable and can be released over an extended time period. In an embodiment, release rate is controlled by the specific weight average molecular weight of the silk fibroin-based protein fragments used. In another embodiment, release rate is controlled by creation of a multi-layer structure. For example, multiple films can be cast and dried upon each other. Additionally, each layer can be formed using the same or different molecular weight compositions. In an embodiment, the degree of crystallinity of the protein structure is altered through film drying conditions, thereby controlling the release rate. The molecule or molecules may be released topically on the skin, subcutaneously following implantation, or locally or systemically through oral administration or implantation. In an embodiment, the molecule or molecules is released between 1 minutes and 20 minutes. In an embodiment, the molecule or molecules is released between 20 minutes and 60 minutes. In an embodiment, the molecule or molecules is released between 1 hour and 4 hours. In an embodiment, the molecule or molecules is released between 4 hours and 8 hours. In an embodiment, the molecule or molecules is released between 8 hours and 24 hours. In an embodiment, the molecule or molecules is released between 1 day and 7 days. In an embodiment, the molecule or molecules is released between 1 week and 4 weeks. In an embodiment, the molecule or molecules is released between 1 month and 3 months. In an embodiment, the molecule or molecules is released between 3 months and 6 months. In an embodiment, the molecule or molecules is released between 20 minutes and 6 months. In an embodiment, the molecule or molecules are stable at extreme temperature and humidity conditions.

Films of the present disclosure comprised of about 20 kDA average weight average molecular weight silk fibroin-based protein fragments and containing about 20% vitamin C by mass, were stored individually within foil pouches and exposed to temperature extremes. Foil pouches containing films were exposed to:

Ambient conditions (time 0 films)

“Extreme Cold” ($-29^{\circ}\text{C} \pm 2^{\circ}\text{C}$. for 72 hours), followed by “Hot Humid” ($38^{\circ}\text{C} \pm 2^{\circ}\text{C}$. at 85% Humidity $\pm 5\%$ for 72 hours), and subsequently “Extreme Heat, Moderate Humidity” ($60^{\circ}\text{C} \pm 2^{\circ}\text{C}$. at 30% Humidity $\pm 5\%$ for 6 hours)

The amount of active vitamin C was measured using HPLC. All films were observed to support maintenance of vitamin C activity with exposure to extremes, as summarized in Table 17.

TABLE 17

Amount of active vitamin C in films under varying conditions			
N	Conditions	Average Conc of vit C in sample (mg/g)	Std. Dev
4	Time 0, ambient conditions	184.90	15.15
16	1) $-29^{\circ}\text{C} \pm 2^{\circ}\text{C}$. for 72 hours	193.97	10.25
	2) $38^{\circ}\text{C} \pm 2^{\circ}\text{C}$. at 85% Humidity $\pm 5\%$ for 72 hours		
	3) $60^{\circ}\text{C} \pm 2^{\circ}\text{C}$. at 30% Humidity $\pm 5\%$ for 6 hours		

FIGS. 37-45 are photographs showing silk protein fragment-films of the present disclosure dried under various temperature, time and drying conditions.

FIGS. 46-54 are photographs showing the dissolution, in water, of the formed silk protein fragment-films of the present disclosure under various temperature, time and drying conditions. The water solubility of films of the present disclosure may be varied by altering drying conditions. For example, drying a film to 20% humidity in a forced air incubator and then increasing ambient humidity to 50% for a period of hours and subsequently drying the film back to 20% humidity will result in an insoluble film. Under ordinary conditions where the humidity is steadily decreased, a water-soluble silk film is created. It is anticipated that the increase in humidity allowed the protein structure to be further mobilized in the film and further crystallized, resulting in a non-soluble film. Alternative methods in the art to create non-soluble films include the introduction of methanol. The films of the present disclosure are clearly differentiated from those films due to their solubility in water. The SFP gel articles described herein range from a hydrogel which can be injected or spread topically to a film-gel article that appears as a film and contains a minimal but controlled water content, thereby preventing crystallinity and allowing water solubility.

In some embodiments, a composition of the present disclosure can further include skin penetration enhancers, including, but not limited to, sulfoxides (such as dimethylsulfoxide), pyrrolidones (such as 2-pyrrolidone), alcohols (such as ethanol or decanol), azones (such as laurocapram and 1-dodecylazacycloheptan-2-one), surfactants (including alkyl carboxylates and their corresponding acids such as oleic acid, fluoroalkylcarboxylates and their corresponding acids, alkyl sulfates, alkyl ether sulfates, docusates such as dioctyl sodium sulfosuccinate, alkyl benzene sulfonates, alkyl ether phosphates, and alkyl aryl ether phosphates), glycols (such as propylene glycol), terpenes (such as limonene, p-cymene, geraniol, farnesol, eugenol, menthol, terpineol, carveol, carvone, fenchone, and verbenone), and dimethyl isosorbide.

Following are non-limiting examples of suitable ranges for various parameters in and for preparation of the silk solutions of the present disclosure. The silk solutions of the present disclosure may include one or more, but not necessarily all, of these parameters and may be prepared using various combinations of ranges of such parameters.

In an embodiment, the percent silk in the solution is less than 30%. In an embodiment, the percent silk in the solution is less than 25%. In an embodiment, the percent silk in the solution is less than 20%. In an embodiment, the percent silk in the solution is less than 19%. In an embodiment, the percent silk in the solution is less than 18%. In an embodiment, the percent silk in the solution is less than 17%. In an embodiment, the percent silk in the solution is less than 16%. In an embodiment, the percent silk in the solution is less than 15%. In an embodiment, the percent silk in the solution is less than 14%. In an embodiment, the percent silk in the solution is less than 13%. In an embodiment, the percent silk in the solution is less than 12%. In an embodiment, the percent silk in the solution is less than 11%. In an embodiment, the percent silk in the solution is less than 10%. In an embodiment, the percent silk in the solution is less than 9%. In an embodiment, the percent silk in the solution is less than 8%. In an embodiment, the percent silk in the solution is less than 7%. In an embodiment, the percent silk in the solution is less than 6%. In an embodiment, the percent silk in the solution is less than 5%. In an

In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 50 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 60 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 70 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 80 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 90 to 100%. In an embodiment, the silk fibroin-based fragments of the present disclosure are non-soluble in organic solutions.

In an embodiment, the percent water content in gels of the present disclosure is 20% to 99.9%. In an embodiment, the percent water content in gels of the present disclosure is 20% to 25%. In an embodiment, the percent water content in gels of the present disclosure is 25% to 30%. In an embodiment, the percent water content in gels of the present disclosure is 30% to 35%. In an embodiment, the percent water content in gels of the present disclosure is 35% to 40%. In an embodiment, the percent water content in gels of the present disclosure is 40% to 45%. In an embodiment, the percent water content in gels of the present disclosure is 45% to 50%. In an embodiment, the percent water content in gels of the present disclosure is 50% to 55%. In an embodiment, the percent water content in gels of the present disclosure is 55% to 60%. In an embodiment, the percent water content in gels of the present disclosure is 60% to 65%. In an embodiment, the percent water in gel cosmetic gels of the present disclosure is 65% to 70%. In an embodiment, the percent water content in gels of the present disclosure is 70% to 75%. In an embodiment, the percent water content in gels of the present disclosure is 75% to 80%. In an embodiment, the percent water content in gels of the present disclosure is 80% to 85%. In an embodiment, the percent water content in gels of the present disclosure is 85% to 90%. In an embodiment, the percent water content in gels of the present disclosure is 90% to 95%. In an embodiment, the percent water content in gels of the present disclosure is 95% to 99%.

In an embodiment, the percent water content in films of the present disclosure is 20%. In an embodiment, the percent water content in films of the present disclosure is less than 20%. In an embodiment, the percent water content in films of the present disclosure is less than 18%. In an embodiment, the percent water content in films of the present disclosure is less than 16%. In an embodiment, the percent water content in films of the present disclosure is less than 14%. In an embodiment, the percent water content in films of the present disclosure is less than 12%. In an embodiment, the percent water content in films of the present disclosure is less than 10%. In an embodiment, the percent water content in films of the present disclosure is between about 2% and about 20%.

In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is greater than 84° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is less than 100° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 84° C. to 100° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 84° C. to 94° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 94° C. to 100° C.

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the described embodiments, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (e.g. amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is weight average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

EXAMPLES

Example 1

Development of a Silk Film of the Present Disclosure for Use in Fine Line Lifting Applications

TABLE 18

Film Recipe for Fine Line Lifting Film - FIG. 82A	
% SPF Mixture Solution of the Present Disclosure	2.4%
Quantity Vitamin C	4:1 (silk:Vit C) (0.006 g/mL 2.4% solution) 20%
mL per film (2.5 cm by 10 cm)	7.08 mL
Mass of silk per film:	170 mg
Mass of l-ascorbic acid per film:	42.5 mg
pH	4.0 (when water is applied)

Silk films (2.5 cm×10 cm) were manufactured according to methods disclosed herein varying process parameters so as to result in fine line lifting films. The silk films were given the name "PureProC™ film", and can be packaged in a foil based package that is air tight and light proof. Table 18 provides details of the PureProC™ films used in a study of 32 individuals using the films for four (4) weeks. Biocompatibility and hypo-allergenicity of the films was observed. Further, no sensitization, toxicity, or immune response was observed. FIG. 84 is a graph summarizing the quantity of vitamin C in a daily dose (i.e., the average amount of product used to cover a 25 cm² area of skin) of PureProC™ and competitor products over a 30 day period. FIGS. 85 and 86 summarize resultant ease of use data and observed benefits within the first month of use.

In an embodiment, PureProC™ films were removed by peeling the films off. In an embodiment, PureProC™ films were removed by using a wet cotton ball or similar removal pad. In an embodiment, PureProC™ films were removed by washing the area where the film is placed with a wash cloth. In an embodiment, PureProC™ film PureProC™ films were removed using water. The PureProC™ films can be shaped into strips for multiple areas of the face or larger pieces can be cut to fit target areas. In an embodiment, grips or backing(s) on the PureProC™ films can be included for ease of application. In an embodiment, a PureProC™ film of the present disclosure includes silk and vitamin C (20%).

In an embodiment, a film of the present disclosure is soluble in water (insoluble border). In an embodiment, a film of the present disclosure is clear/transparent. In an embodiment, a film of the present disclosure has a pH=4 when water is applied. Films of the present disclosure can be made with

different combinations of % silk and volume to produce films with silk quantities of 3 mg/cm² to 10 mg/cm². Films of the present disclosure can be made with from about 1% to about 50% L-ascorbic acid. Films of the present disclosure can adhere to skin with water. Films of the present disclosure can be spread on skin once water is applied. Films of the present disclosure can dry when humidity of drying equipment is 16-40% and below the humidity of the lab

Example 2

Development of Silk Gels of the Present Disclosure

TABLE 19

Gel Samples - Silk gel formulations including additives, concentration of silk and additive, gelation conditions and gelation times.

Sample Name	mL 2% silk solution	Mass Vit C (g)	Ratio silk:VitC	Additive	Amount of additive	Temp/Treatment	Days to Gelation
1	10	0.04	5:01	None	None	RT	8
2	10	0.08	2.5:1	None	None	RT	8
3	10	0.2	1:01	None	None	RT	8
4	10	0.4	1:02	None	None	RT	14
5	10	0.8	1:04	None	None	RT	None
6	10	0.04	5:01	None	None	Fridge	~39
7	10	0.08	2.5:1	None	None	Fridge	~39
8	10	0.2	1:01	None	None	Fridge	~39
9	10	0.4	1:02	None	None	Fridge	None
10	10	0.8	1:04	None	None	Fridge	None
11	10	0.2	1:01	None	None	RT/Shake vigorously	8
O-1	10	0.04	5:01	None	None	37 C. Oven	3
O-2	10	0.04	5:01	None	None	50 C. Oven	2
O-3	10	0.2	1:01	None	None	37 C. Oven	4
O-4	10	0.2	1:01	None	None	50 C. Oven	3
M	40	0.16	5:01	None	None	RT	5
D	40	0.16	5:01	None	None	RT	5
E1	10	0.04	5:01	Vit E	1 drop	RT	7
E2	10	0.04	5:01	Vit E	3 drops	RT	7
E3	10	0	None	Vit E	1 drop	RT	None
E4	10	0	None	Vit E	3 drops	RT	None
L1	10	0.04	5:01	Lemon	300 uL	RT	6
L2	10	0.04	5:01	Lemon Juice	300 uL	RT	6
L3	10	0.04	5:01	Lemon Juice	1000 uL	RT	5
L4	10	0	None	Lemon	300 uL	RT	6
L5	10	0	None	Lemon Juice	300 uL	RT	7
Jar 1	20	0.08	5:01	Lemon Juice	2000 uL	RT	5-7
Jar 2	5	0.02	5:01	Lemongrass Oil	1 drop	RT	2-3
R-1	10	0.04	5:01	Rosemary Oil	1 drop	RT	7
T-1	10	0.04	5:01	None	None	RT/Tube	7
RO-1	10	0.04	5:01	Rose Oil	1 drop	RT	6
RO-2	10	None	None	Rose Oil	1 drop	RT	None

Ratio of Silk to Vitamin C

Samples 1-10 were used to examine the effect of silk to vitamin C ratio on serum gelation. Samples 1-3 with less vitamin C gelled quicker than samples 4 and 5. All other conditions were kept constant. Samples 6-8 with less vitamin C gelled quicker than samples 9 and 10. All other conditions were kept constant. It is concluded that decreasing the ratio of silk to vitamin C (increasing the amount of vitamin C), will lengthen the time to gel creation. At ratios with small amounts of vitamin C, days to gel creation did not vary greatly.

Physical Stimulation

Samples 3 and 11 were used to examine the effect of physical stimulation on serum gelation. Each sample was prepared under the same conditions. Sample 11 was vigorously shaken for about 3 minutes after addition of vitamin C. Treatment of 3 and 11 was otherwise the same. The shaking resulted in bubbles but did not significantly change gel creation time.

Temperature Treatment

Samples 1, 3, 6, 8, O-1, O-2, O-3, and O-4 were used to examine the effect of temperature treatment on serum gelation time. Samples 1, 6, O-1, and O-2 were identical other than temperature treatment. Samples 3, 8, O-3, and O-4 were identical other than temperature treatment. The two groups differed in silk to vitamin C ratio. Time to serum gelation was directly related to temperature treatment with a higher temperature resulting in quicker serum gelation.

Solution Volume

Samples 1, M and D were used to examine the effect of solution volume on serum gelation time. Samples M and D varied from sample 1 only by an increased solution volume.

Samples M and D gelled in 5 days while sample 1 gelled in 8 days. Samples M and D were definitively noticed to be gelled on the day of gelling while sample 1 gelled over a weekend.

Additives

Samples E1, E2, E3, E4, L1, L2, L3, L4, L5, Jar 2, R1, RO-1 and RO-2 were used to examine the effect of additives on serum gelation time. Samples E1-4 contained Vitamin E. Only samples E1 and E2 contained vitamin C and only these two samples gelled. Vitamin E can be added to a solution to become a gel but it appears that another additive may be needed to create a gel. Samples L1-5 contained a form of lemon juice. Samples L1 and L4 had juice directly from a lemon while samples L2, L3 and L5 contained lemon juice from a plastic lemon container. Samples L4 and L5 did not have vitamin C while all others did. All samples gelled showing that lemon juice can create gel on its own. Amount of lemon juice and type of lemon juice had little effect on

gelation time. Sample Jar 2 contained lemon grass oil which formed an albumen like substance when initially added. This sample also had vitamin C but gelation time was significantly quicker than with other vitamin C samples. Sample R1 contained rosemary oil, which seemed to be soluble, as well as vitamin C. The sample gelled in a similar time frame to other samples with only vitamin C. Samples RO-1 and RO-2 contained rose oil while only RO-1 had vitamin C. Only RO-1 gelled showing that rose oil will not create a gel quickly on its own. In both cases the rose oil was immiscible and visible as yellow bubbles.

Aqueous silk fibroin-based fragment solution and essential oils are immiscible liquids. In an embodiment, to increase the fragrance of the silk fibroin-based fragment solution, without entrapping oils within the solution, the solution is mixed with the essential oil with the use of a stir bar. The stir bar is rotated at a speed such that some turbulence is observed in the mixture, thus causing contact between the fragrant essential oil and the molecules in solution, adding a scent to the solution. Before casting of product from the solution, mixing may be stopped and the oil allowed to separate to the top of the solution. Dispensing from the bottom fraction of the solution into the final product allows for fragrance without visible essential oil within the final product.

Alternatively, the silk fibroin-based solution and essential oil can be combined with or without additional ingredients and/or an emulsifier to create a composition containing both ingredients.

In an embodiment, mixing of the solution as described above can reduce gelation time if the solution is used to create a gel formulation.

Vessel

Samples T1 and Jar 1 were used to examine the effect of casting vessel on serum gelation time. Jar 1 was cast in a glass jar while T1 was cast in an aluminum tube. Both samples gelled and did not affect serum gel time.

SUMMARY

All treatments of silk solution for gel solution were in a conical tube at room temperature unless otherwise stated. The ratio of silk to vitamin C did affect the ability of a solution to gel as ratios above 1:2 did not gel and a 1:2 ratio took twice as long as other lower ratios (5:1, 2.5:1, 1:1). Temperature affected gel creation time with higher temperatures resulting in quicker gel times. 50° C. treatment gelled in as quick as 2 days, 37° C. treatment gelled in as quick as 3 days, room temperature treatment gelled in 5-8 days and storage in a refrigerator took at least 39 days to gel. The effects of additives on gel creation were dependent on the additive. Vitamin E, Rosemary Oil and Rose Oil all had no effect on gel creation. Each of these additives did not prevent gelation or affect the time to gelation. Each also required the presence of vitamin C to gel. Lemon juice from a fresh lemon, pre-squeezed lemon juice from a plastic lemon container and lemon grass oil did affect gel creation. Without wishing to be bound by theory, it is believed that the lower pH as a result of these additives is the reason the additives had an impact on decreasing gelation time. Both lemon juice types were able to cause gelation without the presence of vitamin C. This occurred in the same number of days as with vitamin C. The lemongrass oil was able to decrease the number of days to gelation to 2-3 days. All additives appeared soluble other than lemongrass oil and rose oil. Rose oil remained in yellow bubbles while the lemongrass oil was partially soluble and formed an albumen like chunk.

In an embodiment, oils that are not fully soluble, can still be suspended within the gel as an additive. Physical stimulation by shaking, vessel the solution was cast into and solution volume did not affect gelation time. FIG. 81 is a graph representing the % Activity of Vitamin C in gels of the present disclosure.

TABLE 20

Concentration of vitamin C in various gel formulations.			
Sample Info	Sample Weight (mg)	Concentration of Vitamin C (mg/g)	
		In Sample	Average
Rosemary (Room Temperature storage)	685.7	3.2511	3.2657
Lemongrass (Room Temperature storage)	638	3.3336	3.3334
Rosemary (Room Temperature; Foil Covered storage)	646	2.8672	2.877
Lemongrass (Room Temperature; Foil Covered storage)	645.5	2.8868	2.9051
Rosemary (Room Temperature; Foil Covered storage)	645.2	2.9051	2.9051
Lemongrass (Room Temperature; Foil Covered storage)	649	3.9063	3.9147
Rosemary (Fridge, Foil Covered storage)	649	3.923	3.9374
Lemongrass (Fridge, Foil Covered storage)	630.1	3.9443	3.9374
Rosemary (Fridge, Foil Covered storage)	660.4	3.8253	3.8274
Lemongrass (Fridge, Foil Covered storage)	660.4	3.8295	3.8253
Rosemary (Fridge, Foil Covered storage)	672.4	3.8283	3.8253
Lemongrass (Fridge, Foil Covered storage)	616.5	3.8222	3.8253
Rosemary (Fridge, Foil Covered storage)	640.5	5.1616	5.1484
Lemongrass (Fridge, Foil Covered storage)	640.5	5.1352	5.1484
Rosemary (Fridge, Foil Covered storage)	627.7	5.1984	5.201
Lemongrass (Fridge, Foil Covered storage)	627.7	5.2036	5.201
Rosemary (Fridge, Foil Covered storage)	627.7	5.1871	5.1824
Lemongrass (Fridge, Foil Covered storage)	627.7	5.1776	5.1824
Rosemary (Fridge, Foil Covered storage)	627.7	5.2098	5.2126
Lemongrass (Fridge, Foil Covered storage)	627.7	5.2154	5.2126

Example 3

Development of Silk Gels of the Present Disclosure for Use as Smoothing Gel

TABLE 21

Lemongrass Gel	
% Silk Solution	2%
Quantity Vitamin C	100 mg/15 mL solution
Quantity Lemongrass Oil	20 uL/15 mL solution

TABLE 22

Rosemary Gel	
% Silk Solution	2%
Quantity Vitamin C	100 mg/15 mL solution
Quantity Rosemary Oil	20 uL/50 mL solution

TABLE 23

Lemongrass Gel (50 mL)	
% Silk Solution (60 minute boil, 25 kDA)	2%
Quantity Vitamin C (ascorbyl glucoside)	12.82 mg/mL solution (641 mg total)

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TABLE 23-continued

Lemongrass Gel (50 mL)	
Quantity Lemongrass Oil	1.33 uL/mL solution
pH	4

TABLE 24

Rosemary Gel (50 mL)	
% Silk Solution (60 minute boil, 25 kDA)	2%
Quantity Vitamin C (ascorbyl glucoside)	12.82 mg/mL solution (641 mg total)
Quantity Rosemary Oil	0.8 uL/mL solution
pH	4

Gels of the present disclosure can be made with about 0.5% to about 8% silk solutions. Gels of the present disclosure can be made with ascorbyl glucoside at concentrations of about 0.67% to about 15% w/v. Gels of the present disclosure be clear/white in color. Gels of the present disclosure can have a consistency that is easily spread and absorbed by the skin. Gels of the present disclosure can produce no visual residue or oily feel after application. Gels of the present disclosure do not brown over time.

Silk gels with essential oils were prepared by diluting a silk solution of the present disclosure to 2%. Vitamin C was added to the solution and allowed to dissolve. The essential oil was added, stirred and dissolved. The solution was aliquot into jars.

A trial was conducted with 44 people on two formulations of the present disclosure, PureProC™ Rosemary Gel and PureProC™ Lemongrass Gel (FIGS. 87 and 88). Respondents were asked to use each sample once a day for a week each. The majority of respondents applied the gel to the whole face. Other areas where it was most commonly applied included the forehead, under eyes and near mouth.

The majority of respondents applied the gel during the morning (67%) with the balance 33% applying the gel in the evening. Ninety-eight (98%) of participants used the gel once a day during the test. Respondents were asked to describe in their own words how the gel felt when it was applied and how it felt during the 24 hours until the next application. Smooth, cool, and soft were the most often mentioned adjectives used to describe how the gel felt. Eighty percent (80%) of test participants gave a high score to interest in continuing to use the gel.

Respondents were asked about what they did with their other products that were usually used on their face during the trial. The majority applied the gel first and then added the other products or applied the gel at night with no additional products. Only 14% of participants indicated that they eliminated one of their normal products while testing the gel. PureProC™ can be used in conjunction with or in replacement of other products. Additionally, sunscreen can be added to the gel or it may be dispensed from a pump instead of a jar. With repeated topical use, no skin irritation, rash, or signs of non-compatibility was observed. Biocompatibility and hypo-allergenicity of the gels was observed. Further, no sensitization, toxicity, or immune response was observed.

Example 4

Silk Articles of the Present Disclosure Made from Silk Solutions of the Present Disclosure

Silk solutions of various molecular weights and/or combinations of molecular weights can be optimized for specific

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applications. The following provides an example of this process but it not intended to be limiting in application or formulation.

Three (3) silk solutions were utilized in standard silk structures in accordance with standard methods in the literature with the following results:

Solution #1 is a silk concentration of 5.9%, average MW of 19.8 kDa and 2.2 PD (made with a 60 min boil extraction, 100 degree LiBr dissolution for 1 hr)

Solution #2 is a silk concentration of 6.4% (made with a 30 min boil extraction, 60 degree LiBr dissolution for 4 hrs)

Solution #3 is a silk concentration of 6.17% (made with a 30 min boil extraction, 100 C LiBr dissolution for 1 hour)

Films:

Films were made in accordance with Rockwood et al (Nature Protocols; Vol. 6; No. 10; published on-line Sep. 22, 2011; doi:10.1038/nprot.2011.379). Briefly, 4 mL of 1% or 2% (wt/vol) aqueous silk solution was added into 100 mm Petri dish (Volume of silk can be varied for thicker or thinner films and is not critical) and allowed to dry overnight uncovered. The bottom of a vacuum desiccator was filled with water. Dry films were placed in the desiccator and vacuum applied, allowing the films to water anneal for 4 hours prior to removal from the dish. Films cast from solution #1 did not result in a structurally continuous film; the film was cracked in several pieces. These pieces of film dissolved in water in spite of the water annealing treatment.

Egel:

“Egel” is an electrogelation process as described in Rockwood et al. Briefly, 10 ml of aqueous silk solution is added to a 50 ml conical tube and a pair of platinum wire electrodes immersed into the silk solution. A 20 volt potential was applied to the platinum electrodes for 5 minutes, the power supply turned off and the gel collected. Solution #1 did not form an EGEL over the 5 minutes of applied electric current.

Gelation:

Solutions #2 and #3 were gelled in accordance with the published horseradish peroxidase (HRP) protocol. Behavior seemed typical of published solutions.

Sonicated Gels:

Gels were made following the sonication process in Rockwood et al. Briefly, 5 ml of silk solution was added to a 15 ml conical tube. The sonicating horn was immersed in the solution and the solution sonicated at 50% amplitude (21 W). Silk gels were made with 2%, 4% and 6% silk solutions. As compared to standard literature silk, Solutions #2 and #3 formed gels after a longer time, for example:

Standard literature silk: 5-8 min

Solution #2: 20 min

Solution #3: 120 min

Porous 3D Scaffolds:

Water based, salt leached scaffolds were made in accordance with the published methods of Rockwood. Salt with particle sizes of interest was prepared by stacking the sieves with the largest mesh on top and the smallest mesh on the bottom. Salt was added and sieves shaken vigorously collecting the salt. With a 5-ml syringe, 6% (wt/vol) fibroin solution was aliquoted into plastic containers, 2 ml per mold and 5-600 micron salt particles were slowly added on top of the fibroin solution in the mold while rotating the container so that the salt was uniform. The ratio of salt to silk in solution was maintained at 25:1.

The container was gently tapped on the bench top to remove air bubbles, the cap closed and the solution allowed to settle overnight at room temperature. Once gelled, the lids were

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removed and the molds placed in a 2-liter beaker with ultrapure water (three containers per 2 liters of water). The beakers were transferred to a stir plate and stirred, changing the water 2-3 times per day for 2 d (4-6 washes in total). The scaffolds were removed from the molds and placed them in fresh water for an additional day.

Solution #1 did not form a scaffold; it did not gel. Both solution #2 & #3 formed scaffolds. The scaffolds made with Solution #3 appear softer than the ones made with Solution #2, but both scaffolds were homogeneous.

Example 5

Tangential Flow Filtration (TFF) to Remove Solvent from Dissolved Silk Solutions of the Present Disclosure

A variety of % silk concentrations have been produced through the use of Tangential Flow Filtration (TFF). In all cases a 1% silk solution was used as the input feed. A range of 750-18,000 mL of 1% silk solution was used as the starting volume. Solution is diafiltered in the TFF to remove lithium bromide. Once below a specified level of residual LiBr, solution undergoes ultrafiltration to increase the concentration through removal of water. See examples below.

7.30% Silk Solution:

A 7.30% silk solution was produced beginning with 30 minute extraction batches of 100 g silk cocoons per batch. Extracted silk fibers were then dissolved using 100 C 9.3M LiBr in a 100 C oven for 1 hour. 100 g of silk fibers were dissolved per batch to create 20% silk in LiBr. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 15,500 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 1300 mL. 1262 mL of 7.30% silk was then collected. Water was added to the feed to help remove the remaining solution and 547 mL of 3.91% silk was then collected.

6.44% Silk Solution:

A 6.44% silk solution was produced beginning with 60 minute extraction batches of a mix of 25, 33, 50, 75 and 100 g silk cocoons per batch. Extracted silk fibers were then dissolved using 100 C 9.3M LiBr in a 100 C oven for 1 hour. 35, 42, 50 and 71 g per batch of silk fibers were dissolved to create 20% silk in LiBr and combined. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 17,000 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 3000 mL. 1490 mL of 6.44% silk was then collected. Water was added to the feed to help remove the remaining solution and 1454 mL of 4.88% silk was then collected.

2.70% Silk Solution:

A 2.70% silk solution was produced beginning with 60 minute extraction batches of 25 g silk cocoons per batch. Extracted silk fibers were then dissolved using 100 C 9.3M LiBr in a 100 C oven for 1 hour. 35.48 g of silk fibers were dissolved per batch to create 20% silk in LiBr. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 1000 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 300 mL. 312 mL of 2.7% silk was then collected.

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Example 6

Gel Vitamin C Derivatives of the Present Disclosure

The purest form of vitamin C is L-ascorbic acid. There are a number of other derivatives of vitamin C that function like pure vitamin C after they are converted to L-ascorbic acid in the body. Vitamin C derivatives are being utilized to extend shelf life. Derivatives are stable forms of L-ascorbic acid and will not oxidize or lose stability. Table 25 below summarizes some vitamin C derivatives tested in the skin care products of the present disclosure:

TABLE 25

Derivatives Explored

Sodium Ascorbyl Phosphate (Aromatic)
Sodium Ascorbyl Phosphate (DSM)
Magnesium Ascorbyl Phosphate
Ascorbic Acid-2-Glucoside
Ascorbyl Tetraisoalmitate

The Tables in FIGS. 89A-89B summarize embodiments of gels of the present disclosure. Ascorbic acid-2-glucoside was the most successful vitamin C derivative at gel formation with gel being formed in a 2% silk solution in 3 days. Sodium ascorbyl phosphate from DSM supplier formed a gel in a 2% silk solution after 28 days while the same molecule from Aromatic failed to create a gel. In all cases 100 mg of vitamin C derivative was mixed in 15 mL of 2% silk solution, and all gels had the same appearance as gels created with ascorbic acid.

Gels were also cast with combinations of two vitamin C options. In each case, at least one of the vitamin C options was known to cause gelation (L-ascorbic acid or ascorbic acid-2-glucoside). All combination gels were able to gel at 1% total vitamin C additive concentration. A gel cast at 20% total vitamin C additive concentration did not gel. Without wishing to be bound by theory, it appears there is a relationship between vitamin C concentration, silk concentration, and gelation. An increase in vitamin C at a given concentration of silk will result in a longer time to gelation or inhibit gelation. This may be due to the vitamin C molecule physically blocking interaction between silk protein fragments or cross-linking of silk protein. Modification to pH may allow additional concentrations of vitamin C and derivatives thereof to be added.

Ascorbyl tetraisoalmitate was not used in any gel forming formulation, as it was unable to dissolve or be dispersed in an aqueous silk solution. Ascorbyl tetraisoalmitate is a highly viscous, oil soluble liquid that might need the help of an emulsifier to possibly dissolve in aqueous silk solution.

Example 7

Film Vitamin C Derivatives of the Present Disclosure

FIG. 90 is a table summarizing embodiments of films of the present disclosure. Sodium ascorbyl phosphate, magnesium ascorbyl phosphate and ascorbic acid-2-glucoside could be cast in films with varying appearance. Sodium ascorbyl phosphate films were opaque and white with a textured top surface similar to plastic. Magnesium ascorbyl phosphate films were clear and cloudy with a textured top surface similar to plastic. Ascorbic acid-2-glucoside films

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were most similar to L-ascorbic acid films although slightly less pliable and slightly textured. All films were soluble with an insoluble border. In an embodiment, a film with an insoluble border can be made completely spreadable by punching a shape from the region contained within the soluble section.

Example 8

Caffeine Films with Vitamin C of the Present Disclosure

FIGS. 91A-91B are tables summarizing embodiments of caffeine films of the present disclosure. Films were cast with 0.5%, 1%, 2.5%, 5%, 10%, 15% and 20% caffeine and 20% or 25% vitamin C. All combinations formed films. 20% caffeine films had caffeine precipitate out. Films with 0.5%-2.5% were soluble. In an embodiment, a caffeine film of the present disclosure is used for reducing puffy eyes.

Example 9

Caffeine Gels with Vitamin C of the Present Disclosure

A silk gel with 2% silk and 100 mg L-ascorbic acid/15 mL solution was created with the addition of 50 mg caffeine/15 mL solution. The gel has the exact appearance of standard L-ascorbic acid gels. In an embodiment, a caffeine gel of the present disclosure is used for reducing puffy eyes. A range of essential oils can be used including, but not limited to, lemongrass, vanilla, geranium, and green tea.

Example 10

Green Tea Gels with Vitamin C of the Present Disclosure

Steps:

Green Tea Prep	Heat 250 mL water to boil Steep tea bag 2-3 minutes with occasional stir
Gel Solution Prep	remove tea bag and let cool Use TFF-10-0047 (3.71% silk) dilute to 3% silk with water dilute to 2% with green tea add L-ascorbic acid
Gel	Gelation occurred like standard gel at room temperature Green/yellow color Green Tea scent
Solution Spec:	2% silk solution 65 mL (35 ml of 3.71% silk, 8.3 mL water, 21.66 mL green tea) 0.43 g L-ascorbic acid

FIG. 92 is a table summarizing an embodiment of a caffeine gel of the present disclosure. A silk gel with 2% silk and 100 mg L-ascorbic acid/15 mL solution was created with the addition of 50 mg caffeine/15 mL solution. The gel has the exact appearance of standard L-ascorbic acid gels.

Example 11

Preservative Gels with Vitamin C of the Present Disclosure

FIG. 93 is a table summarizing embodiments of preservative gels of the present disclosure. Silk gels were cast with

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standard 2% silk solution and 100 mg L-ascorbic acid/15 mL solution with the addition of a preservative and chelating agent. The preservative added was Verstatil SL by Kinetic (Water, Sodium Levulinate, Potassium Sorbate) at 1.5% and the chelating agent was Dermofeel-PA3 by Kinetic (Sodium Phytate) at 0.1%. The addition of preservatives extended gelation time to 7 days. Gel is being observed for discoloration and integrity with L-ascorbic acid and ascorbic acid-2-glucoside gel comparisons.

Example 12

Chemical Peels of the Present Disclosure

The primary variable investigated was the concentration of lactic acid and/or glycolic acid necessary to create a silk solution of a desired pH. In order to determine the relationship between concentration in silk and pH, 2% silk solutions (60 minute boil, 25 kDA) were titrated with glycolic and lactic acid and tested for pH with pH strips. See the following titrations/formulations below:

TABLE 26

Lactic Acid Peel 1: Initial solution: 25 mL of 2% silk solution, pH = 7-8		
Quantity of Lactic Acid Added	Total Lactic Acid	pH
100 µL	100 µL	3
100 µL	200 µL	2
100 µL	300 µL	1-2

Time to gel: 3 days

TABLE 27

Lactic Acid Peel 2: Initial solution: 25 mL of 2% silk solution, pH = 7-8		
Quantity of Lactic Acid Added	Total Lactic Acid	pH
25 µL	25 µL	4

Time to gel: >5 days

TABLE 28

Glycolic Acid Peel 1: Initial solution: 25 mL of 2% silk solution, pH = 7-8		
Quantity of Glycolic Acid Added	Total Glycolic Acid	pH
41 mg	41 mg	4
43.25 mg	84.25 mg	3
30.7 mg	114.95 mg	3
56.4 mg	171.35 mg	2-3
91.66 mg	263.01 mg	2
171.35 mg	434.4 mg	1-2

Time to gel: 3 days

TABLE 29

Glycolic Acid Peel 2: Initial solution: 25 mL of 2% silk solution, pH = 7-8		
Quantity of Lactic Acid Added	Total Lactic Acid	pH
41 mg	41 mg	4

Time to gel: >5 days

TABLE 30

Lactic/Glycolic Acid Peel: Initial solution: 25 mL of 2% silk solution, pH = 7-8			
Total Lactic Acid	Total Glycolic Acid	Lemongrass	pH
150 μ L	200 mg	33.3 μ L	2

Time to gel: 3 days

TABLE 31

Lactic/Glycolic Acid Peel: Initial solution: 30 mL of 2% silk solution, pH = 7-8	
% Silk Solution (60 minute boil, 25 kDA)	2%
Lactic Acid Concentration	6 μ L/mL
Glycolic Acid Concentration	8 mg/mL
pH	2
Lemongrass Concentration	1.33 μ L/mL

A peel of the present disclosure can have a % silk ranging from about 0.5% to about 8%. The pH of a peel of the present disclosure can be adjusted with varying quantities of lactic and glycolic acid. Peels can also be made with lactic acid only or glycolic acid only. A peel of the present disclosure can be clear/white in color. A peel of the present disclosure can have a gel consistency that is easily spread and absorbed by the skin. A peel of the present disclosure does not brown or change colors.

In an embodiment, a chemical peel of the present disclosure can be applied weekly to reveal healthy, vibrant skin. In an embodiment, a chemical peel of the present disclosure can be applied weekly to diminish fine lines. In an embodiment, a chemical peel of the present disclosure can be applied weekly to firm the skin.

Each formulation (after titration, if applicable) was applied as a liquid and as a gel and observed for look and feel. Peels of pH=4 (Lactic Acid Peel 2, Glycolic Acid peel 2) resulted in a minimal burning feeling after a few minutes of application, while peels of pH \approx 2 (Lactic Acid Peel 1, Glycolic Acid Peel 1, Lactic/Glycolic Acid Peel) caused a slightly more intense burning feel. Little difference in degree of burning was felt between liquid and gel other than that the burning sensation was more delayed in the gel form. PH was maintained in the gel form and was confirmed by using a pH strip.

Glycolic acid and lactic acid are both alpha hydroxy acids (AHA's) that are among the most commonly used peels for superficial peeling (outermost skin layer peeling). Chemical peels are intended to burn the top layers of the skin in a controlled manner, to remove superficial dermal layers and dead skin in order to improve appearance. AHAs are common in chemical peels due to low risk of adverse reactions and high control of strength (control pH and time applied). Glycolic acid is most commonly used and has a very small molecular size, enabling deep penetration into the epidermis. Lactic acid is another commonly used AHA and offers a more gentle peel with higher control due to its larger molecular size. Any number of chemicals known in the art that lower pH and are physical exfoliates can be used in place of AHAs.

Example 13

Hydrating Serums of the Present Disclosure

Variables include: concentration of silk in solution, concentration of HA, addition of vitamin C, and serum preparation method. Table 32 is a list of samples that were evaluated:

TABLE 32

Embodiments of serums of the present disclosure containing HA and Silk (60 minute boil, 25 kDA), with or without vitamin C, and with 20 μ L/15 mL lemongrass essential oil (30 mL solution)				
Method	HA (%)	Silk (%)	Vit C (mg)	Observation
HA added to water before dilution of silk	0.5	2	0	White, slightly opaque, viscous liquid
	1			White/yellow, slightly opaque, viscous liquid
	0.5	2	0	Low viscosity, clear-white opaque with film on top, some white residue when applied topically to skin
	1			Slightly viscous, clear liquid with film on top
	0.5	1	0	Slightly viscous, clear liquid with film on top
	1			Smooth viscous liquid, no white residue when applied topically to skin
	0.5	0.5	0	Moderately viscous liquid, clear
	1			Smooth, clear, no white residue when applied topically to skin
	0.5	2	35	Non homogeneous mix of hard gel and viscous liquid
	1			Non homogeneous mix of hard gel and viscous liquid
HA added to water before dilution of silk, stirred vigorously	1	1	35	Non homogeneous mix of hard gel and viscous liquid
		0.5		Opaque, white liquid/non-viscous
	1	4	35	Separated mixture of hard gel and viscous liquid
			0	Non homogeneous mix of hard gel and viscous liquid
	5	2	0	Yellow, gel
	10	2	0	Viscous jelly upon stirring with undissolved HA
	5			Very viscous jelly upon stirring
	1			Viscous jelly upon stirring
		0.5		

TABLE 32-continued

Embodiments of serums of the present disclosure containing HA and Silk (60 minute boil, 25 kDA), with or without vitamin C, and with 20 μ L/15 mL lemongrass essential oil (30 mL solution)				
Method	HA (%)	Silk (%)	Vit C (mg)	Observation
HA added to water before dilution of silk, shaken	1 5	2 1	0 0	Non homogeneous thick, viscous jelly/gel
HA added to water and let sit for 1 day before dilution of silk	1	1	0	Clear/slightly opaque, viscous liquid, smooth feel, little to no white residue when applied topically to skin
HA added to diluted silk solution, stirred	0.5 1 0.5 1	2 1 6	0	Viscous, clear/white liquid varying in consistency Clear viscous liquid varying in consistency White, opaque jelly varying in consistency
HA added to diluted silk solution, stirred	0.5 1 0.5 1	3.9 2	0 35	White, slightly opaque, viscous liquid White gel varying in consistency

In an embodiment, a hydrating serum of the present disclosure protects the skin and seals in moisture with the power of silk fibroin-based fragment proteins. In an embodiment, a hydrating serum of the present disclosure delivers moisture for immediate and long-term hydration throughout the day with concentrated hyaluronic acid. A range of essential oils can be used in a hydrating serum of the present disclosure including, but not limited to, lemongrass, vanilla, geranium, and green tea. In an embodiment, one or two drops of a hydrating serum of the present disclosure can be smoothed over the face and neck. In an embodiment, a hydrating serum of the present disclosure includes water, aqueous silk fibroin-based fragment solution, hyaluronic acid, and lemongrass oil. In an embodiment, the silk fibroin-based fragment protein in a hydrating serum of the present disclosure has the ability to stabilize and protect skin while sealing in moisture, all without the use of harsh chemical preservatives or synthetic additives. In an embodiment, the hyaluronic acid in a hydrating serum of the present disclosure nourishes skin and delivers moisture for lasting hydration. In an embodiment, the lemongrass essential oil in a hydrating serum of the present disclosure yields antioxidant and anti-inflammatory properties that support skin rejuvenation. In an embodiment, a hydrating serum of the present disclosure has a pH of about 6.0.

Silk Fibroin-Based Fragment Solution

Because silk fibroin-based fragment solution is both aqueous and able to entrap and deliver small molecules, the solution is able to deliver both water and hygroscopic HA molecules to the skin for hydration. A range in concentration of silk fibroin-based fragment compositions in solution from 0.5%-6.0% was tested for feasibility and product outcome. All concentrations tested were found to be feasible.

Hyaluronic Acid

Hyaluronic acid (Sodium Hyaluronate) was tested as an ingredient in the hydrating serum due to its hygroscopic properties and ability to promote soft, hydrated skin. A range in concentration of hyaluronic acid in solution from 0.5%-10.0% was tested for feasibility and product outcome. All concentrations tested, with the exception of 10.0%, were found to be feasible. Feasibility was determined based on the ability to dissolve hyaluronic acid.

Vitamin C and Derivatives Thereof

Vitamin C (L-ascorbic acid) was tested as an ingredient in the hydrating serum. Initial vitamin C samples became a non-homogeneous mixture of gel and liquid. A follow-up trial with vitamin C resulted in a homogeneous, white, opaque, non-viscous liquid that was not quickly absorbed by the skin. In an embodiment, a vitamin C derivative that does not readily cause gelation, such as sodium ascorbyl phosphate, could be added up to the concentration at which it would no longer be soluble (for example, 0% to about 40%). In an embodiment, 20% sodium ascorbyl phosphate could be added. Vitamin C options that do cause gelation (L-ascorbic acid and ascorbyl glucoside) could be added at high concentrations (for example greater than about 10% up to about 50%) at which gelation is inhibited.

Serum Creation Method

Initial serums were created by the addition of HA to a silk fibroin-based fragment solution followed by stirring. The HA appeared to stick together and was not dissolved until forcefully stirred. The mixing process was then changed so that HA was first dissolved in water and then immediately used to dilute a high concentration silk fibroin-based fragment solution (>4%) to the desired concentrations. The resulting serums were more homogeneous and had a desirable smooth, clear look and feel. Upon application to the skin, a white residue briefly appeared that could be rubbed in. In an alternate method formulations were created by dissolving HA in water and allowing it to sit for 1 day until complete dissolution was observed. The HA and water solution was then used to dilute a high concentration silk fibroin-based fragment solution to the desired concentrations. The resulting serum was clear, smooth, homogeneous and left little to no white residue when applied.

Example 14

UV Hydrating Serums of the Present Disclosure

Variables tested include: concentration of HA, concentration of zinc oxide, concentration of titanium dioxide, addition of vitamin C, and serum preparation method.

FIGS. 94A-94C are tables summarizing embodiments of cosmetic serums of the present disclosure with varying additives and concentrations of components suitable for protection against ultraviolet radiation (UV). Table 33 provides an embodiment of a hydrating serum of the present disclosure with vitamin C.

TABLE 33

Embodiment of Hydrating serum of the present disclosure with vitamin C	
% Silk Solution (60 minute boil, 25 kDA)	1.0% w/v
Hyaluronic Acid (sodium hyaluronate)	0.75% w/v
Lemongrass Oil	20 uL/15 mL silk solution
Sodium Ascorbyl Phosphate	6 g
Lactic Acid	1.2 mL

A serum of the present disclosure can be made with from about 0.25% to about 10% sodium hyaluronate (increasing % results in more viscous serum). 0.5% to about 10% silk solutions can be used to prepare a serum of the present disclosure. A serum of the present disclosure can be clear and have a yellow tinted color. A serum of the present disclosure can have a pH=6. A serum of the present disclosure can have a lubricious texture that is rubbed in easily without residue.

Concentration of HA:

Hyaluronic acid (Sodium Hyaluronate) was tested as an ingredient in the UV silk serum due to its hygroscopic properties and widely accepted use in cosmetic products to promote hydration of skin. 1%, 2.5% and 5% HA solutions were tested. With increasing HA %, the serum became more viscous and gel like. 1% HA was not feasible for the UV serum due to the fact that the UV additives (zinc oxide, titanium dioxide) are not water soluble and need to be dispersed. 1% HA was not viscous enough for dispersion and the UV additives precipitated out. 2.5% gave the best consistency based on preferred feel, texture and viscosity and was able to disperse the UV additives. 5% was a very thick, viscous serum.

Concentration of Mineral Filters: Zinc Oxide and Titanium Dioxide:

Zinc oxide and titanium dioxide were explored as UV additives that are considered safe. These additives mechanically protect from UV radiation by forming a physical reflective barrier on the skin. Both are not soluble in water and must be dispersed for the current aqueous solution. Zinc oxide concentration varied from 2.5%, 3.75%, 5%, 5.625%, 10%, 12% and 15%. Titanium dioxide concentrations varied from 1.25%, 1.875%, 3%, 5% and 10%. Increasing the concentration of UV additives resulted in minor increases of white residue and how well dispersed the additives were, however if mixed well enough the effects were negligible. Zinc oxide and titanium dioxide were mixed together into serums in order to achieve broad spectrum protection. Zinc oxide is a broad spectrum UV additive capable of protecting against long and short UV A and UV B rays. However titanium dioxide is better at UV B protection and often added with zinc oxides for best broad spectrum protection. Combinations included 3.75%/1.25% ZnO/TiO₂, 5.625%/1.875% ZnO/TiO₂, 12%/3% ZnO/TiO₂, 15%/5% ZnO/TiO₂. The 3.75%/1.25% ZnO/TiO₂ resulted in spf 5 and the 5.625%/1.875% ZnO/TiO₂ produced spf 8.

Vitamin C:

Sodium ascorbyl phosphate was used as a vitamin C source. Formulations were created with the vitamin C concentration

equal to that in the silk gel (0.67%). Formulations were also created with 20% sodium ascorbyl phosphate which is soluble in water.

Serum Preparation:

The vitamin C (sodium ascorbyl phosphate) must first be dissolved in water. Sodium hyaluronate is then added to the water, mixed vigorously and left to fully dissolve. The result is a viscous liquid (depending on HA %). The viscosity of the HA solution allows even dispersion of the zinc oxide and titanium dioxide and therefore HA must be mixed before addition of UV additives. The zinc oxide and titanium dioxide are then added to the solution and mixed vigorously with the use of an electric blender. Silk solution is then added and mixed to complete the serum formulation.

15 Chemical Filters:

A UV serum of the present disclosure can include one, or a combination of two or more, of these active chemical filter ingredients: oxybenzone, avobenzone, octisalate, octocrylene, homosalate and octinoxate. A UV serum of the present disclosure can also include a combination of zinc oxide with chemical filters.

In an embodiment, a UV serum of the present disclosure can be applied approximately 15 minutes before sun exposure to all skin exposed to sun, and can be reapplied at least every 2 hours. In an embodiment, a UV serum of the present disclosure includes water, zinc oxide, sodium hyaluronate, titanium dioxide, silk, and vitamin C or a vitamin C derivative such as sodium ascorbyl phosphate. In an embodiment, a UV serum of the present disclosure protects skin and seals in moisture with the power of silk protein. In an embodiment, a UV serum of the present disclosure improves skin tone, promotes collagen production and diminishes the appearance of wrinkles and fine lines with the antioxidant abilities of vitamin C. In an embodiment, a UV serum of the present disclosure delivers moisture for immediate and long-term hydration throughout the day with concentrated hyaluronic acid. In an embodiment, a UV serum of the present disclosure helps prevent sunburn with the combined action of zinc oxide and titanium dioxide. In an embodiment, a UV serum of the present disclosure is designed to protect, hydrate, and diminish fine lines while shielding skin from harsh UVA and UVB rays. In an embodiment, the silk protein in a UV serum of the present disclosure stabilizes and protects skin while sealing in moisture, without the use of harsh chemical preservatives or synthetic additives. In an embodiment, the vitamin C/derivative in a UV serum of the present disclosure acts as a powerful antioxidant that supports skin rejuvenation. In an embodiment, the sodium hyaluronate in a UV serum of the present disclosure nourishes the skin and delivers moisture for long-lasting hydration. In an embodiment, the zinc oxide and titanium dioxide in a UV serum of the present disclosure shields skin from harmful UVA and UVB rays. The silk protein stabilization matrix in a UV serum of the present disclosure protects the active ingredients from the air, to deliver their full benefits without the use of harsh chemicals or preservatives. The silk matrix also traps moisture within the skin furthering the hydrating effect of the sodium hyaluronate.

Example 15

Dark Spot Films of the Present Disclosure

To reduce the appearance of dark spots, a high concentration of vitamin C may be necessary to reverse the overproduction of melanin. In this example, a 40% vitamin C (1.5:1 silk to vitamin C) was studied. The size and shape of

the film can be made appropriate to a targeted area, for example to a small circular film of diameter 1 in (2.54 cm).

The dark spot film, or a similar film of the present disclosure, of varying vitamin C concentration (0-50%) can be applied as a hydrofilm. Skin can be wetted with water. The film is then applied to the wet area. Water is then applied to the top surface of the film to turn it into a gel. The gel can then be spread and gently massaged into the application area. Table 34 provides details of an embodiment of a hydrofilm of the present disclosure (with no insoluble border).

TABLE 34

An Embodiment of a hydrofilm of the present disclosure	
% Silk Solution (60 minute boil, 25 kDA)	2.56%
Quantity Vitamin C (l-ascorbic acid)	15.62 mg total (10 mg in 1 in circle punch out)
Volume of solution per mold	2.44 mL
Film Size	1.25 in diameter circle (7.917 cm ²)

A film of the present disclosure can be made with different combinations of % silk and volume to produce films with silk quantities of 3 mg/cm² to 10 mg/cm². A film of the present disclosure can be made with from about 1% to about 50% l-ascorbic acid. A film of the present disclosure is soluble in water (insoluble border is removed by punching out the center of the film). A film of the present disclosure can adhere to skin with water. A film of the present disclosure can be spread on skin once water is applied. A film of the present disclosure can be dried when the humidity of drying equipment is 16-40% and below the humidity of the lab. A film of the present disclosure can be clear/transparent.

In an embodiment, a dark spot film of the present disclosure includes water, silk, and vitamin C (L-ascorbic acid). In an embodiment, a dark spot film of the present disclosure includes 40% vitamin C. In an embodiment, a dark spot film of the present disclosure reduces skin pigmentation and evens skin tone in a targeted area with daily use. Vitamin C can inhibit pigment transfer from pigment producing cells, called melanocytes, to skin surface cells with continual application. In an embodiment, a dark spot film of the present disclosure can be applied to clean, dampened skin for 20 minutes. In an embodiment, additional water can be applied to an adhered film. The silk protein stabilization matrix in a dark spot film of the present disclosure protects the active ingredients from the air, to deliver their full benefits without the use of harsh chemicals or preservatives, such as paraben and phthalate. Thus, a dark spot film of the present disclosure is paraben and phthalate-free. Table 35 provides details of an embodiment of a film of the present disclosure.

TABLE 35

An Embodiment of a Film of the Present Disclosure	
% Silk Solution (60 minute boil, 25 kDA)	2.2%
Surface area	5.07 cm ²
Volume of silk solution for casting	1.56 mL
Mass of silk per film:	34 mg
Mass of l-ascorbic acid per film:	23 mg
Concentration of l-ascorbic acid in film:	40%
pH	3

A 2.1% silk solution of the present disclosure (0.321 mL/cm²) to 2.4% silk solution of the present disclosure

(0.282 mL/cm²) can be used to create dark spot films of the present disclosure with 34 mg of silk (6.7 mg/cm²). In an embodiment, a 2.2% silk solution of the present disclosure (60 minute boil, 25 kDA) is used to produce a film of the present disclosure. The % silk and volume of solution can vary to produce equivalent films. A dark spot film of the present disclosure can be made with different combinations of % silk and volume to produce films with silk quantities of 3 mg/cm² to 10 mg/cm². A dark spot film of the present disclosure can be made with from about 15 to about 50% l-ascorbic acid. A dark spot film of the present disclosure is soluble in water (insoluble border). A dark spot film of the present disclosure is clear/transparent. A dark spot film of the present disclosure has a pH=3 when water is applied. A dark spot film of the present disclosure can adhere to skin with water. A dark spot film of the present disclosure can dry when humidity of drying equipment is 16-40% and below the humidity of the lab

Example 16

High Concentration Vitamin C Gels of the Present Disclosure

High concentration vitamin C gels were pursued up to 20%. Vitamin C type, vitamin C concentration, % silk and pH were varied to increase the quantity of vitamin C in a gel.

FIGS. 95A-95C are tables summarizing embodiments of high concentration vitamin C gels of the present disclosure. The highest concentration of vitamin C to gel was a 15% ascorbic acid 2 glucoside gel with 3.8% silk solution after 12 days. 5 and 10% ascorbic acid-2-glucoside formulations with 2, 3 and 3.8% silk all gelled. For each group of % vitamin C, gelation first occurred in the 3.8% silk followed by the 3% and lastly the 2%. It appears that there is a relationship between vitamin C concentration, silk concentration and gelation. If a solution has too much vitamin C in relation to silk, gelation will be prevented. Therefore, in order to produce high concentration vitamin C gels, higher concentration silk is necessary. One sample was cast at 5.5% silk and 20% vitamin C but gelation did not occur and a higher % silk may be necessary. Samples were also brought to a pH of 2 with lactic acid in order to help induce gelation in 3% silk solutions with 10 or 20% vitamin C, however gelation did not occur in 12 days.

Example 17

Microbiological Study of Gels of the Present Disclosure

Contaminating micro-organisms in cosmetics may cause a spoilage of the product and, when pathogenic, they represent a serious health risk for consumers worldwide. The United States Pharmacopoeia (USP) Microbial Limits Test provides several methods for the determination of total microbial count for bacteria, yeast and mold. Various gels of the present disclosure were tested to evaluate the possible microbial contamination in three different states of their use (intact, in-use, ending product). FIG. 96 is a table summarizing the results of such testing.

The samples of gel and water samples from carboys were analyzed for determination of CFU/mL (colony-forming units per milliliter) of aerobic bacteria as well as yeast and mold. Samples were exposed to growth medium of Tryptic Soy Agar (TSA) for bacteria and Potato Dextrose Agar (PDA) for fungi (yeast/mold) at an exposure temperature of

23±3° C. Samples were incubated at 30.0±2° C. for 3 days (bacteria) and 5 days (Fungi). Samples were then observed for determination of colony-forming units/mL.

The limit of detection for the assays was 10 CFU/ml or g for bacteria and fungi, and the values of <10 indicate that microorganisms could not be detected in the samples. Values of >1.00E+04 indicate that the microbial colonies are Too Numerous to Count in the dilutions plated.

Example 18

UV Silk Foams and Liquids of the Present Disclosure

In an embodiment, the vitamin C derivative sodium ascorbyl phosphate (DSM) was dissolved in water. Sodium hyaluronate (“HA”) was then added to the water, mixed vigorously, and left to fully dissolve. The result is a viscous liquid (depending on HA %). The viscosity of the HA solution allows even dispersion of the zinc oxide and titanium dioxide and therefore HA is typically mixed before addition of UV additives. The zinc oxide and titanium dioxide are added to the HA solution and mixed vigorously, for example with the use of an electric blender. 60 minute boiled (~25 kDa) silk solution is then added and mixed to create a 1% silk formulation.

Two formulations were created without the addition of sodium ascorbyl phosphate (samples “HU2” and “HU4”). For sample HU2, zinc oxide and titanium dioxide were added and mixed by blending with an electric blender and whisk. The result was a viscous white liquid (FIG. 98 and FIG. 99). Silk was then added and blended with an electric blender and whisk. The solution became a creamy foam similar to shaving cream (FIG. 97 and FIG. 100). Vitamin E in the form of dl-alpha tocopheryl acetate can be added to the solution to recover a viscous liquid texture that can be applied with a smooth even texture (FIG. 98). With increasing the quantity of dl-alpha tocopheryl acetate, the formulation will become less foam-like and more of a smooth liquid or lotion texture.

HU4 was split into two batches: FIG. 99, batch 2 and FIG. 100, batch 1. The first batch followed the same procedures to HU2 and became a foam. For the second batch of HU4, sodium ascorbyl phosphate was added and dissolved before adding any zinc, titanium or silk. The UV additives were then added by blending with an electric blender and whisk and created a standard white viscous liquid. Silk was then added with an electric blender and whisk. The result was slightly thicker viscous liquid than normally seen. Without wishing to be bound by theory, it appears the addition of sodium ascorbyl phosphate inhibits foaming. Without wishing to be bound by theory, it appears that whisking, as opposed to mixing or blending, creates a silk foam.

TABLE 36

Embodiments of UV Silk Foams and Liquids of the Present Disclosure									
Sample	Total Volume	% silk	% HA (sodium hyaluronate)	Mass HA (g)	% ZnO	Mass ZnO (g)	% TiO ₂	Mass TiO ₂ (g)	Sodium Ascorbyl Phosphate (g)
HU2	55	1	2.5	1.375	12	6.6	3	1.65	N/A
HU4	27.5	1	3.5	0.9625	12	3.3	3	0.825	5.5
Batch 1									
HU4	27.5	1	3.5	0.9625	12	3.3	3	0.825	N/A
Batch 2									

Example 19

Lyophilized Silk Powders of the Present Disclosure

TABLE 37

Embodiments of lyophilized silk powders		
Silk Solution	Treatment	Soluble
~60 kDa silk, 6% silk, pH = 7-8	lyophilize and cut with blender	no
~60 kDa silk, 6% silk, pH = 10	lyophilize and cut with blender	no
~25 kDa silk, 6% silk, pH = 7-8	lyophilize and cut with blender	yes
~25 kDa silk, 6% silk, pH = 10	lyophilize and cut with blender	yes

The above silk solutions were transformed to a silk powder through lyophilization to remove bulk water and chopping to small pieces with a blender. pH was adjusted with sodium hydroxide. Low molecular weight silk (~25 kDa) was soluble while high molecular weight silk (~60 kDa) was not.

The lyophilized silk powder can be advantageous for enhanced storage control ranging from 10 days to 10 years depending on storage and shipment conditions. The lyophilized silk powder can also be used as a raw ingredient in the pharmaceutical, medical, consumer, and electronic markets. Additionally, lyophilized silk powder can be re-suspended in water, HFIP, or an organic solution following storage to create silk solutions of varying concentrations, including higher concentration solutions than those produced initially.

In an embodiment, aqueous pure silk fibroin-based protein fragment solutions of the present disclosure comprising 1%, 3%, and 5% silk by weight were each dispensed into a 1.8 L Lyoguard trays, respectively. All 3 trays were placed in a 12 ft² lyophilizer and a single run performed. The product was frozen with a shelf temperature of ≤-40° C. and held for 2 hours. The compositions were then lyophilized at a shelf temperature of -20° C., with a 3 hour ramp and held for 20 hours, and subsequently dried at a temperature of 30° C., with a 5 hour ramp and held for about 34 hours. Trays were removed and stored at ambient conditions until further processing. Each of the resultant lyophilized silk fragment compositions were able to dissolve in aqueous solvent and organic solvent to reconstitute silk fragment solutions between 0.1 wt % and 8 wt %. Heating and mixing were not required but were used to accelerate the dissolving rate. All solutions were shelf-stable at ambient conditions.

In an embodiment, an aqueous pure silk fibroin-based protein fragment solution of the present disclosure, fabri-

cated using a method of the present disclosure with a 30 minute boil, has a molecular weight of about 57 kDa, a polydispersity of about 1.6, inorganic and organic residuals of less than 500 ppm, and a light amber color.

In an embodiment, an aqueous pure silk fibroin-based protein fragment solution of the present disclosure, fabricated using a method of the present disclosure with a 60 minute boil, has a molecular weight of about 25 kDa, a polydispersity of about 2.4, inorganic and organic residuals of less than 500 ppm, and a light amber color.

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa includes the steps of: degumming a silk source by adding the silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 60° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in an oven having a temperature of about 140° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of silk protein fragments, the aqueous solution comprising: fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The aqueous solution of pure silk fibroin-based protein fragments may be lyophilized. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide. A film may be fabricated from the aqueous solution of pure silk fibroin-based protein fragments produced by this method. The film may comprise from about 1.0 wt. % to about 50.0 wt. % of vitamin C or a derivative thereof. The film may have a water content ranging from about 2.0 wt. % to about 20.0 wt. %. The film may comprise from about 30.0 wt. % to about 99.5 wt. % of pure silk fibroin-based protein fragments. A gel may be

fabricated from the aqueous solution of pure silk fibroin-based protein fragments produced by this method. The gel may comprise from about 0.5 wt. % to about 20.0 wt. % of vitamin C or a derivative thereof. The gel may have a silk content of at least 2% and a vitamin content of at least 20%.

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa includes the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, wherein the aqueous solution of silk protein fragments comprises sodium carbonate residuals of between about 10 ppm and about 100 ppm, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The aqueous solution of pure silk fibroin-based protein fragments may be lyophilized. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide. A film may be fabricated from the aqueous solution of pure silk fibroin-based protein fragments produced by this method. The film may comprise from about 1.0 wt. % to about 50.0 wt. % of vitamin C or a derivative thereof. The film may have a water content

ranging from about 2.0 wt. % to about 20.0 wt. %. The film may comprise from about 30.0 wt. % to about 99.5 wt. % of pure silk fibroin-based protein fragments. A gel may be fabricated from the aqueous solution of pure silk fibroin-based protein fragments produced by this method. The gel may comprise from about 0.5 wt. % to about 20.0 wt. % of vitamin C or a derivative thereof. The gel may have a silk content of at least 2% and a vitamin content of at least 20%.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, the method including the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of about 30 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, sodium carbonate residuals of between about 10 ppm and about 100 ppm, fragments having an average weight average molecular weight ranging from about 40 kDa to about 65 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The aqueous solution of pure silk fibroin-based protein fragments may be lyophilized. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide. A film may be fabricated from the aqueous solution of pure silk fibroin-based protein fragments produced by this method. The film may comprise from about 1.0 wt. % to about 50.0 wt. % of vitamin C or

a derivative thereof. The film may have a water content ranging from about 2.0 wt. % to about 20.0 wt. %. The film may comprise from about 30.0 wt. % to about 99.5 wt. % of pure silk fibroin-based protein fragments. A gel may be fabricated from the aqueous solution of pure silk fibroin-based protein fragments produced by this method. The gel may comprise from about 0.5 wt. % to about 20.0 wt. % of vitamin C or a derivative thereof. The gel may have a silk content of at least 2% and a vitamin content of at least 20%.

All patents, patent applications, and published references cited herein are hereby incorporated by reference in their entirety. While the methods of the present disclosure have been described in connection with the specific embodiments thereof, it will be understood that it is capable of further modification. Further, this application is intended to cover any variations, uses, or adaptations of the methods of the present disclosure, including such departures from the present disclosure as come within known or customary practice in the art to which the methods of the present disclosure pertain.

What is claimed is:

1. A composition comprising:

- pure silk fibroin-based protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the fragments have an average weight average molecular weight ranging from about 6 kDa to about 16 kDa,
- wherein the fragments have a polydispersity of from about 1.5 to about 3.0,
- wherein the composition is substantially homogeneous, wherein the composition includes between 0 ppm to 500 ppm of inorganic residuals,
- wherein the composition includes between 0 ppm to 500 ppm of organic residuals, and
- wherein the composition does not spontaneously or gradually gelate and does not visibly change in color or turbidity when in a solution for at least 10 days.
2. The composition of claim 1 wherein the inorganic residuals include lithium bromide residuals and wherein the organic residuals include sodium carbonate residuals.
3. The composition of claim 2 wherein the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay.
4. The composition of claim 1 wherein the solution is an aqueous solution.
5. The composition of claim 1 in a sealed container.
6. The composition of claim 1 further comprising poly-anhydrides.
7. The composition of claim 1 further comprising vitamin C or a derivative thereof.
8. The composition of claim 1 further comprising an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid, and citric acid.
9. The composition of claim 1 further comprising hyaluronic acid or its salt form at a concentration of about 0.5 wt. % to about 10.0 wt. %.
10. The composition of claim 1 further comprising at least one of zinc oxide or titanium dioxide.
11. The composition of claim 1 wherein the pure silk fibroin-based protein fragments are hypoallergenic.
12. The composition of claim 1 having less than 10 colony forming units per gram.

13. The composition of claim 1, wherein the composition does not spontaneously or gradually gelate and does not visibly change in color or turbidity when in a solution for at least 30 days.

14. The composition of claim 1 wherein the average weight average molecular weight range and the polydispersity are measurable using a high-performance liquid chromatography assay.

15. The composition of claim 1, wherein the fragments have an average weight average molecular weight ranging from 10 kDa to 15 kDa.

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